DOCUMENT RESUME

ED 327 377 SE 051 822

AUTHOR	Tisher, Richard P., Ed.
TITLE	Research in Science Education, Volume 19, 1989. Selected Refereed Papers from the Annual Conference of the Australian Science Education Research Association. Held at the Frankston Campus of the Chisholm Institute of Technology (20th, Victoria, New South Wales, Australia, July 1989).
INSTITUTION	Australian Science Education Research Association.
REPORT NO	ISSN-0157-244X
PUB DATE	89
NOTE	322p.; For Volumes 17 and 18 see ED 319 587 and ED 318 625.
AVAILABLE FROM	Business Manager, Faculty of Education, Monash University, Clayton, Victoria 3168, Australia.
PUB TYPE	Collected Works - Conference Proceedings (021)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Academic Achievement; Case Studies; Cognitive Development; *College Science; *Elementary School Science; Elementary Secondary Education; Foreign Countries; Higher Education; *Misconceptions; Problem Solving; *Professional Development; Science Activities; Science Education; Science Teachers; *Secondary School Science; Student Projects; *Teacher Education; Teaching Methods
IDENTIFIERS	Australia; *Science Education Research

ABSTRACT

Diverse themes from the annual conference of the Australian Science Education Research Association are addressed in this volume. New topic concerns as well as concerns that have been cited in previous issues are identified. Papers focus on issues including: (1) science and technology; (2) classroom practices and processes; (3) international research; (4) professional development; (5) student attitudes; (6) scientific literacy; (7) student misconceptions; (8) student achievement; and (9) textbooks. Research notes, the addresses of authors, and guidelines for the submission of papers are provided. (KR)

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ED327377

ISSN 0157-244X

Research In Science Education

Volume 19

1989

Annual publication of the Australian Science Education Research Association

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Research In Science Education

Volume 19

1989

Annual publication of the **Australian Science Education Research Association**

Selected refereed papers from the Twentieth Annual Conference of the Australian Science Education Research Association, held at the Frankston campus of the Chisholm Institute of Technology, Victoria, July 1989.

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General correspondence about this publication should be addressed to Dr. Paul Gardner, Faculty of Education, Monash University, Clayton, Victoria, Australia 3168.

Subscriptions and orders should be sent to the Business Manager, Professor Richard T. White, Faculty of Education, Monash University, Clayton, Victoria, Australia 3168.

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Published by Australian Science Education Research Association

ISSN 0157-244X

Printed by Monash University Printery, Clayton, Victoria, Australia.

CONTENTS

Page

Editorial comments (vi)

Guidelines for authors (vii)

Addresses of authors (ix)

P.F. Andrew, J.M. Owen, & R.E. Hurworth
Increasing participation in science mathematics and technology education: Hats off to CAPS? 1

K. Appleton
A learning model for science education 13

H.H. Birnie
The alternative conceptions of a particle theory of air possessed by year 1-5 primary students, their parents, and their teachers 25

W. Bucat, & G. Williams
Student note-taking in chemistry lectures 37

R.T. Cross, & R.F. Price
Science education in the long shadow of Michael Polanyi 47

G. Dall'Alba, E. Walsh, J. Bowden, E. Martin, F. Marton, G. Masters, P. Ramsden, & A. Stephanou
Assessing understanding: A phenomenographic approach 57

J.A. Clarke, & B.C. Dart
Target students in year 8 science classrooms: A comparison with and extension of existing research 67

R. Fawns
"Coping with the modern world." The context and the debate at the Australian Science Education Project Guidelines Conference 1970 76

H.J. Fearn-Wannan
Education and science - the state of the union 86

M. Finegold, & R. Trumper
Categorizing pupils' explanatory frameworks in energy as a means to the development of a teaching approach 97

L. Gao, H. Adcock, M. Carr, A. Hume, D. Nicholson, J. Silvester and D. Smith
An account of action research investigating teacher change 112

G.J. Giddings, and B.J. Fraser
Development of an instrument for assessing the psychosocial environment of science laboratory classes 123

B. Hand
Student understandings of acids and bases: A two year study 133

D. Hayes, & D. Symington
Techniques used by primary school pupils in drawings during science activities 145

O.J. Jegede, & B.J. Fraser
Influence of socio-cultural factors on secondary school students' attitude towards science 155

A.J. Jones, & C.M. Kirk
Teaching technological applications in the physics classroom 164

V. Kirkwood, M. Bearlin, & T. Hardy
New approaches to the inservice education in science and technology of primary and early childhood teachers (or Mum is not dumb after all 174

M.R. Matthews
Galileo and pendulum motion: A case for history and philosophy in the science classroom 187

I. Mitchell
The influence of class dynamics on individual learning 198

W.P. Palmer
Gold mining in Papua New Guinea: A curricular omission? 210

L.F. Rennie, and D.F. Treagust
Measuring students' attitudes and perceptions about technology: A multidimensional concept 221

P. Rice
Thai conceptions of illness 231

R.A. Schibeci
Desperately seeking science (and technology?) 241

A.W. Scott
Inservice for elementary teachers in science education - some directions for the future 249

K. Skamp
General Science knowledge and attitudes towards science and science teaching of pre-service primary teachers: Implications for pre-service units 257

B. Stanbridge
Some classroom applications of current ideas on conceptual learning in science 268

D. Symington, & D. Hayes
What do you need to know to teach science in the primary school? 278

I. Torrie
Developing achievement-based assessment using grade related criteria 286

D. Treagust, R. Duit, I. Lindauer, & P. Joslin
Teachers' use of analogies in their regular teaching routines 291

R.J. Werry
Meaning and values from science texts 300

EDITORIAL COMMENT

This issue of Research in Science Education once again demonstrates the rich range of science education research currently being undertaken in Australia. The topics under investigation are diverse. Several studies focus on the learning of science concepts, while others are concerned with the study of teacher behaviour, the evaluation of government initiatives, the philosophy of science, in-service teacher education, and many other issues. The papers also reflect a wide variety of research methods: the historical analysis of scholarly writings, naturalistic observations of teachers and learners and interviews to reveal learners' conceptual structures are all represented here. The scope is broad: although, for understandable reasons, research on secondary school science remains dominant, it is good to see increasing attention being given to primary and tertiary science education. And there is a good geographic mix: in addition to the many contributions from various states, there are papers relating to education in Nigeria, Israel, Thailand, Papua New Guinea and New Zealand.

As I write these words, the Australian Science Education Research Association is celebrating its 20th anniversary. In May, 1970, after several months of preliminary work by Peter Fensham, Dick White and other colleagues at Monash, the first ASERA conference was held at Monash University. The subsequent history of the organisation has been remarkable. We have no formal membership procedure, no annual subscription, no formal election of office-bearers. What we do have is a healthy professional association, a lively and well-attended annual conference, and a quality journal which makes a respected contribution to the international science education research community.

The first two issues of this journal were named Research 1971 and Research 1972; the next issue was named Science Education Research 1973. The founding editor was Dick Tisher, then at the University of Queensland. In the preface to the first issue -- inserted as a loose erratum sheet as it had been omitted from the bound copy! -- Dick wrote that it was

> part of an embryonic project. A dream is that one day there will be an Australian journal reporting exclusively on research projects in science education. Hopefully, this present collection of papers is a precursor of a journal of research in science education.

Prophetic use of language. The dream was fulfilled, word for word, in 1974, when Research in Science Education was adopted as the permanent name for this journal. In that year, Dick took up a chair at Monash and subsequently relinquished the editorship, but he accepted it again after our first New Zealand conference, in 1983. Dick has done much of the editorial work for this issue. (My contribution has been limited to proof-reading the final copy and seeing it through to publication.) This is an appropriate time to express our appreciation to him as he leaves Monash to become head of the Victorian Curriculum and Assessment Board. His new position will be a challenging one; he takes it up at a time of public controversy over assessment methods for the new Victorian Certificate of Education. We thank him for his work in founding this journal, and wish him well in his new appointment.

Paul Gardner,
Acting Editor.

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CORRELATIONS BETWEEN ANXIETY AND RUNNING SPEED

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Fig. 3 A model of the learning process

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AUTHOR

DR MARY SMITH, Senior Lecturer, Faculty of Education, University of Central Australia, Alice Springs, NT 0870.
Specializations: biotechnology curriculum development, biology teacher education.

Acting Editor: Dr P.L. Gardner, Faculty of Education, Monash University, Clayton, Victoria, Australia 3168.

ADDRESSES OF AUTHORS

Adcock, H.
C/- Prof. M. Carr
University of Waikato
Hamilton NEW ZEALAND

Andrew, P.F.
Institute of Education
University of Melbourne
PARKVILLE VIC 3052

Appleton, K.
University College of Central
Queensland
ROCKHAMPTON QLD 4700

Bearlin, M.
Canberra CAE
PO Box 1
BELCONNEN ACT 2616

Birnie, H.H.
University of Saskatchewan
Saskatoon
CANADA S7N OWO

Bowden, J.
C/- Dr G. Dall'alba
University of Melbourne
PARKVILLE VIC 3052

Bucat, W.
School of Chemistry
University of Western Australia
NEDLANDS WA 6009

Carr, M.
University of Waikato
Hamilton NEW ZEALAND

Clarke, J.A.
Brisbane CAE
Victoria Park Road
KELVIN GROVE QLD 4069

Cross, R.T.
School of Education
La Trobe University
BUNDOORA VIC 3083

Dall'alba, G.
University of Melbourne
PARKVILLE VIC 3052

Dart, B.C.
Brisbane CAE
Victoria Park Road
KELVIN GROVE QLD 4069

Duit, R.
Institute for Science Education
University of Kiel
Kiel WEST GERMANY

Fawns, R.
Institute of Education
University of Melbourne
PARKVILLE VIC 3052

Fearn-Wannan, H.J.	15 Carawatha Road DONCASTER VIC 3108
Finegold, M.	Israel Institute of Technology Technion City Haifa ISRAEL 3200
Fraser, B.J.	Curtin University of Technology PO Box 1987 PERTH WA 6001
Gao, L.	C/- Prof. M. Carr University of Waikato Hamilton NEW ZEALAND
Giddings, G.J.	Curtin University of Technology PO Box 1987 PERTH WA 6001
Hand, B.	Bendigo CAE PO Box 199 BENDIGO VIC 3550
Hardy, T.	Canberra CAE PO Box 1 BELCONNEN ACT 2616
Hayes, D.	Malvern Primary School 27 Tooronga Road MALVERN VIC 3144
Hume, A.	C/- Prof. M. Carr University of Waikato Hamilton NEW ZEALAND
Hurworth, R.E.	Institute of Education University of Melbourne PARKVILLE VIC 3052
Jegede, O.J.	Curtin University of Technology PO Box 1987 PERTH WA 6001
Jones, A.J.	University of Waikato Hamilton NEW ZEALAND
Joslin, P.	Drake University Des Moines, Iowa U.S.A.
Kirk, C.M.	University of Waikato Hamilton NEW ZEALAND
Kirkwood, V.	University of Waikato Hamilton NEW ZEALAND
Lindauer, I.	University of Northern Colorado Greeley, Colorado U.S.A.
Martin, E.	C/- Dr G. Dall'alba University of Melbourne PARKVILLE VIC 3052

Marton, F.	C/- Dr G. Dall'alba University of Melbourne PARKVILLE VIC 3052
Masters, G.	C/- Dr G. Dall'alba University of Melbourne PARKVILLE VIC 3052
Matthews, M.R.	University of New South Wales PO Box 1 KENSINGTON NSW 2033
Mitchell, I.	Faculty of Education Monash University CLAYTON VIC 3168
Nicholson, D.	University of Waikato Hamilton NEW ZEALAND
Owen, J.M.	Institute of Education University of Melbourne PARKVILLE VIC 3052
Palmer, W.P.	Northern Territory University PO Box 40146 CASUARINA NT 0811
Price, R.F.	School of Education La Trobe University BUNDOORA VIC 3083
Ramsden, P.	C/- Dr G. Dall'alba University of Melbourne PARKVILLE VIC 3052
Rennie, L.F.	Curtin University of Technology GPO BOX U1987 PERTH WA 6001
Rice, P.	Victorian Transcultural Psychiatry Unit Health Department of Victoria Park Street PARKVILLE VIC 3052
Schibeci, R.A.	School of Education Murdoch University MURDOCH WA 6150
Scott, A.W.	Centre for Science Maths & Computer Education University of New England ARMIDALE NSW 2350
Silvester, J.	C/- Prof. M. Carr University of Waikato Hamilton NEW ZEALAND

Skamp, K.
Northern Rivers CAE
PO Box 157
LISMORE NSW 2480

Smith, D.
C/- Prof. M. Carr
University of Waikato
Hamilton NEW ZEALAND

Stanbridge, B.
51 Sheehy Road
WHITEROCK QLD 4871

Stephanou, A.
c/- Dr G. Dall'alba
University of Melbourne
PARKVILLE VIC 3052

Symington, D.
Victoria College
Burwood Highway
BURWOOD VIC 3125

Torrie, I.
Waikato University
Hamilton NEW ZEALAND

Treagust, D.F.
Curtin University of Technology
GPO BOX U1987
PERTH WA 6001

Trumper, R.
C/- Dr M. Finegold
Israel Institute of Technology
Technion City
Haifa 32000 ISRAEL

Walsh, E.
C/- Dr G. Dall'alba
University of Melbourne
PARKVILLE VIC 3052

Werry, R.J.
25 Chetwynd Street
WEST MELBOURNE VIC 3003

Williams, G.
C/- Dr W. Bucat
University of Western Australia
NEDLANDS WA 6009

Research in Science Education 1989, 19, 1 - 12,

INCREASING PARTICIPATION IN SCIENCE MATHEMATICS AND TECHNOLOGY EDUCATION: HATS OFF TO CAPS?

Pamela F Andrew, John M Owen and Rosalind E Hurworth

INTRODUCTION

Recently, the public has been made increasingly aware that Australia must become more economically competitive in the international arena. Reports such as Education and National Needs (1987) and Victoria The Next Decade (1987) signal that we can no longer rely on primary products to balance trade accounts. A central argument in these reports is that through skilling the workforce and manufacturing high quality, technologically based products which are in demand internationally, the country will return to economic prosperity.

It is not our intention to discuss the relative contributions of education, business/industry, and the workforce to this economic revival. However, as might be anticipated, schools and other educational agencies must play a part in the education of a more technologically competent society.

A central concern of politicians and educational planners has been the issue of education and training in the areas of science, mathematics and technology [hereafter sm&t). Within this in mind, The Baklien Report, Improving the Science Mathematics and Technology Education Base in Victoria (1987) made a series of recommendations designed to:

- improve education and training in science, mathematics and technology
- ensure an adequate supply of appropriately trained teachers in these areas;
- raise awareness among parents and the community about the need for students to study sm&t subjects throughout their schooling.

The recently developed Curriculum Frameworks for years P-10 and the range of Victorian Certificate of Education subjects for years 11-12 are key avenues for translating policy into action in the school system in this State. A significant and positive aspect of these documents is that most take a 'science technology and society' approach. The inclusion of the society component signifies an emerging interest in environmental and other socially related aspects within sm&t studies.

EMBEDDING SM&T APPROACHES IN THE SCHOOL CURRICULUM

Policy initiatives promoting a strong sm&t focus, such as those described above represent a significant reorientation in emphasis for a majority of schools and teachers. In secondary schools, particularly (as distinct from technical schools), science and mathematics teaching has often been academically orientated and only related to the 'real world' in incidental ways. Consequently, the implementation of new policies represents a challenge for educational planners in assisting schools and teachers to learn and accept new modes of operation.

Given the available knowledge about implementing school level action (see for example Fullan, 1982) which is consistent with new policies, the Ministry of Education [MOE] and other system level agencies have set up a number of curriculum support strategies. While the major thrust is taking place through a professional development program (Initiative 5.4), a range of smaller programs have been initiated to complement the major one.

THE COORDINATED AREAS PROGRAM [CAPS]

One of these smaller programs is the Coordinated Areas Program [CAPS]. The creation of CAPS emerged from the Baklien Report which recommended that

> at least three coordinated area programs be developed and carried out within Victoria involving groups of schools, local industries, tertiary institutions and relevant others to increase the participation of young people in science, mathematics and technology subjects throughout schooling, at Year 12 and postsecondary level' (Baklien report: p9).

Four CAPS sites were set up in late 1987. The MOE provided a seeding grant of $20000 to each site in that year and a further vote of $45000 during 1988. These funds were expected to underwrite establishment costs. The MOE expected each site to raise additional monies from other sources and also made it clear that after two years, each site should examine other sources of funds for their operations.

The term site is used to describe the locus of operation for each of the four individual CAPS initiatives. Within the Geelong Science and Technology Education Project (GMSTEP), for example, there is the host institution, Deakin University, schools, and those businesses and industries which are involved in the CAPS initiative in this location. Other CAPS initiatives are: WESTCAP, hosted by the Footscray Institute of Technology; NIECAP, hosted by Phillip Institute of Technology; and SECAP, jointly hosted by Victoria College and Monash University.

This paper is directly concerned with the impact of CAPS. Because the CAPS program has a specific charter to forge links between schools and other institutions it is worthy of particular investigation at this time.

EVALUATING CAPS

During 1989 the Centre for Program Evaluation was commissioned to carry out an evaluation of the CAPS Program. There were two major purposes of the evaluation:

> - to describe ways in which the [individual site] programs have been managed and implemented and to identify some of the outcomes to a point in time to be decided and
> - to provide a base from which decisions about the extension of the Program can be made by the Ministry (Centre for Program Evaluation, 1989:2)

The evaluation team is documenting developments at each site and recording ways in which each site developed initiatives which increased participation in sm&t education. This approximates to a 'goal free' approach to evaluation suggested originally by Scriven (1973). However, rather than adopting a completely unstructured approach to the data collection and analysis we are using approaches suggested by Miles and Huberman (1984). This involves setting up a conceptual framework from which to facilitate cross-site analysis.

In this framework we identified three phases of development at CAPS sites: establishment, implementation and outcomes.

Establishment refers to the creation of the organisation and structure and rules of operation at each CAPS site.

Implementation refers to the offering of specific programs by each site which are intended to make an impact on students

Outcomes refers to the various ways in which students have participated and been influenced by initiatives and activities sponsored by CAPS sites.

The major focus of this paper is on the establishment phase of the Program.

Achievements of CAPS to date.

We now describe the **achievements** at the four CAPS sites and provide some background about their evolution to the present situation. The term achievements covers the establishment phase and describes the programs which have been set up so far.

The reason for placing an emphasis on establishment is that the structure and early planning within organisations affect the effectiveness of their subsequent offerings. CAPS is still in a relatively early stage of development. Describing the establishment phase within each CAP site will enable the evaluation team to understand the impact of each site at later dates.

Site Specific Achievements. By June 1989 specific programs have either been planned or implemented at all sites. A feature of these developments is that each site has developed its own understanding of its role in encouraging participation in sm&t education.

- **At GMSTEP** the major emphasis has been on developing curriculum materials which can be used to teach mathematics through technological applications. These have been produced after a series of visits by teachers and students to selected industries. The materials are now being refined for general use in schools.

There has been an expansion of links with industry in 1989 and this includes an encouragemnt for teachers spend time in at selected industry sites.

- The approach is to embed GMSTEP within the permanent structures of the MOE. Three teacher 'collaboratives', in science, mathematics and technology have been set up within the Geelong School Support Centre of the

MOE and staff of the Centre have accepted responsibility for future developments within each collaborative.

- A key assumption in this approach is that Geelong schools and teachers will be influenced by CAPS initiatives within the broader context of current educational policy documents [Frameworks, VCE, etc].

- **At WESTCAP** the major emphasis has been on school-institution links involving the Footscray Institute of Technology (FIT). Programs commenced by WESTCAP include:

  * a mobile classroom designed to make technology within science and mathematics more appealing and relevant to students and the public
  * a program designed to make mathematics and science more accessible to secondary students through revised curricula and work experience with a more practical and locally relevant flavour.
  * the creation of special selection and admission procedures (concentrating on STC students in the area) to attract more students to Footscray Institute science/mathematics/teacher education courses.

- The approach is multi-faceted and designed to raise the profile and status of the institution in the community and to increase accessibility to certain sm&t courses for students in the locality.

- A key assumption in this approach is that interest in science/ mathematics and teacher education among school age students will increase and that the FIT will adopt a strong technological emphasis in science and teacher education which caters for these students.

- **At NIECAP** a major emphasis has been on programs offered by the Phillip Institute of Technology (PIT) which are complementary to those offered in schools. NIECAP has been responsible for implementing a series of computer camps for girls in secondary schools, involving local industry, which are designed to increase student knowledge about, and attitudes towards, computers and computer careers.

- The approach is to provide courses most likely to be consistent with a technology/industry/schools focus which are in the interests of students in local schools.

- A key assumption in this approach is that short courses for students which have a technology focus are of value if they offer content and approaches which cannot be easily provided by schools.

- **At SECAP** a major emphasis has been on improving school curricula. SECAP has acted by identifying a small number of schools which had the potential to benefit from a review of various aspects of their mathematics and science curricula.

- The approach is to assist schools in developing a technology focus through direct links with industry.
- A key assumption in this approach is that impact on students is maximised if a technology focus becomes permanently embedded in the school curricula.

Achievements Across Sites. While program initiatives are various and individual, there have been a number of similarities in the establishment of the CAPS sites

- At all sites key individuals have undertaken the ground work to involve schools and industry in cooperative efforts. This has necessitated dissemination of information about the purposes of the CAPS initiative, and follow-up visits to selected schools and industries.
- All sites have now set up formal administrative structures, including management committees. There has been extensive discussion and planning at the management committee and operational levels about programs for 1989.
- Some programs which ran in 1988 are to run again in 1989, in a modified or extended form. Others of a more long term nature will be continuing. A range of new initiatives are in the planning stage.
- Each site has attracted longer term commitment from the host tertiary institution(s).
- Contingent upon the seeding monies supplied by the MOE, some sites have attracted additional monies but there have been variations from site to site in amount . Additional funding seems not to be related to the quality of programs between sites but rather linked to the entrepreneurial nature of some key players, and the extent to which the sites were already engaged in initiatives in sm&t education before the CAPS initiative was launched.
- Each of the sites is committed to local evaluation of their programs, a process which is providing important information from which to assess the impact of these local efforts.

Accounting for Achievements to Date

In this section of the paper we examine ways in which the CAPS project was set up. A full account of the development of an educational initiative should include information, not only about the achievements, but also about events, procedures and key decisions which have led to these achievements.

Setting up the sites and interpretations of the Program. Informal networks which existed between the MOE and the host institutions provided considerable impetus for creating CAPS. This was evident in Recommendation R15 of the Baklien Report, which reflected directions that some site initiatives were already taking. . Also, the sites chosen had the potential to turn R15 into action quickly and each possessed one or two key players who were the prime movers behind the initiatives.

In three of the four sites ideas had already been developed and programs were at least in the planning stage. Therefore CAPS supported and legitimised existing initiatives and provided them with resources and a formal backing from the MOE. SECAP was the exception in this regard.

Selection of sites also took account of the need for 'geographical completeness' at least in the major metropolitan areas of the State. To achieve this an application to become a CAPS site from Victoria College/Monash University was accepted even though it had no major initiative under way.

While recommendation R15 of the Baklien Report contained a statement about the creation of CAPS this was not intended as a policy directive. Rather, the approach adopted by the MOE was to treat the creation of the four CAPS as an experimental Program. In this pilot stage the approach was one of allowing each site to do much as it wished rather than one of planned central change. While this approach appears to have been accepted within the sites there have been some who would have appreciated more structure, with at least one site leader feeling that greater direction was required.

The implication is that the MOE is using this pilot stage as the basis for learning about the range of possibilites for improving sm&t through the particular arrangements embodied in CAPS. The time now seems appropriate for policy makers to consider how much of what has been learned might be used in developing directions for future CAPS initiatives.

Resourcing the Program. While the core money provided by the MOE to each site was the same there were variations in the extent to which sites attracted further monies other than those provided by the MOE. Where there were high visibility initiatives in the planning stage or in action in 1988, there was a related attraction of additional funds.

MOE involvement and funds were thus used as a lever to attract other sources of revenue, with variation in the extent to which key players have become involved in extra fund-raising. At this stage it is clear that the programs offered at all sites should not be thought of as solely MOE sponsored programs; they are more accurately thought of a site initiatives supported by a range of funders.

It should also be noted that while external monies have funded the majority of the CAPS initiatives, host institutions have also contributed additional assistance by housing the initiatives, involving staff with existing fixed commitments, and providing secretarial support.

Developing structures and links with industry. Key players tended to be upper/middle level academics in the institutions with a particular interest in sm&t. Roles in 1988 included; liaison with the MOE, launching programs, setting up committees, and raising money.

Deakin and Footscray have opted for a 'dispersed' executive approach while the other two sites have appointed a part-time project officer to manage day-to-day affairs. There are indications of high workloads for the latter as the scope of the work of each CAP expands and diversifies.

There have been variations in the extent to which formal committees have determined directions. While in some cases committees sanctioned directions already decided on by key players, in other cases they have had a key role in decision-making.

Each site set out to develop links with schools and industry, and considerable effort was put into this in 1988. Personal contacts of major players was the key to establishing networks. While contacts with schools has been relatively easy, making effective links with industry for the purposes of implementing programs has not been simple. Contacts through NIECAP have been easier than at other sites because Phillip Institute had already built up extensive links with industry prior to CAPS. Disseminating information about the functions of CAPS has been, and will continue to be important. There is now an emphasis on the use of informal networks to spread the word about CAPS to representatives from industry. Such people are in middle level management, rather than being 'captains of industry'.

There is a lack of knowledge of developments in sm&t education by staff in industry (and even by staff in some tertiary institutions). This is related to structures in that many firms in the industry/business sector do not have arrangements for liaising with the educational system. This has major implications for the implementation of the VCE.

DISCUSSION

In 1987 key individuals were identified by the MOE and provided with resources to implement programs in sm&t. Working with colleagues in their tertiary institutions and elsewhere, they have initiated a range of small scale sm&t programs through CAPS. Given a high degree of freedom at the site level each CAP has pursued a different line of action based on a site level interpretation of its role as an agent for improving participation in technologically based programs in mathematics and science.

Development to date has required considerable effort from those centrally involved. A wide variety of initiatives are already in place. In addition there is now a firm basis of organisation and goodwill from which CAPS programs can affect a larger number of students in schools, to influence their subject choices and, ultimately, their participation in tertiary science/mathematics programs.

Given the small amount of seeding money supplied by the MOE, and the effort required to orientate many industries towards the needs of the education system, the extent of development within CAPS to this time is impressive.

The evaluation team is now involved in monitoring the implementation and outcomes phases of the Program and will report on them later in the year.

Important issues are emerging. For example, at the implementation phase, the evaluation has pointed out that CAPS sites need to take into account the ongoing developments in policy and school level program delivery in schools. (Owen, Hurworth and Andrew, 1989). An issue increasingly being addressed by steering committees at each site is "how does this fit in with the school curriculum in sm&t?"

This reminds us that as long ago as 1964, Miles coined the phrase 'temporary system', for educational support structures designed to effect change and improvements during a limited life span. Given the documented lack of impact of many temporary systems it is now of interest to determine the extent to which CAPS is able to cooperate with more permanent structures within the MOE and other agencies. To inform this issue the evaluation team has carried out an analysis of approaches to the teaching of technology which has been distributed to CAPS sites (see the Appendix).

This paper has described a wide range of programs supported across the sites. Thus there will be a range of outcomes and the evaluation team is presently working on a framework for describing how CAPS has increased student participation in sm&t education.

CONCLUDING COMMENT

While there is an important role for the evaluation in accounting for the work within CAPS, the possibility of an expansion of CAPS to more sites is an encouragement for the evaluation to provide guidelines for their operation. A conclusion from this 'first round' is that there is no best way for a CAPS site to operate. Rather, guidelines for future sites are likely to be in the form of options, each with advantages and disadvantages, from which new sites can choose in the light of existing needs and resources. Laying out these options will become a major focus for the final stages of the evaluation should decision makers agree to an expansion of the CAPS Program.

REFERENCES

AUSTRALIAN SCIENCE AND TECHNOLOGY COUNCIL. Education and National Needs. A report to the Prime Minister by the Australian Science and Technology Council. Canberra: Canberra Publishing and Printing. 1987.

CENTRE FOR PROGAM EVALUATION. An evaluation of the Coordinated Areas Project [CAPS]. Unpublished paper prepared for the CAPS Steering Committee, Melbourne, February 1989.

FULLAN, M. The Meaning of Educational Change. Toronto: OISE Press and New York: Teachers College Press. 1982.

MILES, M.B. On Temporary Systems. in Miles, M.B. [Ed.] Innovation in Education. New York: Teachers College Press. 1964.

MILES, M.B. & HUBERMAN, A.M. Qualitative Data Analysis. Beverly Hills, California: Sage. 1984.

OWEN, J.M. HURWORTH, R.E. & ANDREW, P.F. An evaluation of the establishment phase of the Coordinated Areas Program. Report to the Evaluation Committee of the Coordinated Areas Program. April 1989.

SCRIVEN, M. Goal Free Evaluation. In House, E. R. [Ed] School Evaluation. Berkeley, California: McCutchan. 1973.

VICTORIAN GOVERNMENT. Improving the science mathematics and technology base in Victoria. The report of the working group on education for science and technology to the Victorian government through the Hon. Ian Cathie, Minister for Education. (A Baklien, Chairperson). Melbourne, August 1987.

VICTORIAN GOVERNMENT. Victoria The Next Decade. Leading Australia into the Next Decade. Melbourne. Government Printer. April 1987.

Appendix. Recommendation R15 of the Baklien Report and changes in school curricula: some implications for policy and practice.

As part of the evaluation the relevant section of the Baklien Report was examined because it was the one centrally produced statement for setting directions for the CAPs. It states:

> 'School influences, home and demographic influences, community influences and the availability of transfer between, and entrance to, tertiary study were the four groupings of factors identified as influencing **students' perceptions** of their ability and their **perceptions of career and employment opportunities** in the science, mathematics and technology areas. Therefore the most effective strategy for increasing **student participation** is to coordinatc a series of intervention strategies within the four groupings'.
>
> > R15 That at least three CAPS be developed and carried out within Victoria involving groups of schools, local industries and relevant others to **increase the participation** of young people in science, mathematics and technology subjects throughout schooling, at Year 12 and postsecondary level.
>
> 'The plan is to include strategies to improve the **images** held within the home, the school and the community concerning maths, science and technology and **concerning careers** or employment in these areas. Strategies for **transfer** between and entrance to postsecondary study should also be included. **Places** such as science centres...[etc]......should be incorporated where appropriate' (p10) (our emphasis in highlighting).

Examining the statement in sections suggests the following

[1] R15 emphasises **participation**. This appears to be the central outcome of the the initiative. Research, for example relating to the Participation and Equity Program, shows that there are many interpretations of educational participation. There may be a need for those associated with CAPS sites to consider the meanings most relevant to their sites.

[2] The preamble implies a link between four blocks of factors and student perceptions of their **abilities and career opportunities**.

[3] The final part of the statement implies a need to improve **images** held by society of courses and careers in science, mathematics and technology.

The goals and outcomes implied in [2] and [3] are longer term in nature While they are important it is not appropriate to link them directly to the initiatives and programs undertaken through CAPS.

[4] It is important that there be some additional thinking about the meanings of technology and the place of technology in the school curriculum.

In R15, the use of the phrase 'science, mathematics and technology' might be interpreted to mean that CAPS initiatives in technology need to fit into the study of Technology subjects in schools, rather than more broadly influence established school science and mathematics subjects. Such an interpretation is understandable given developments in curriculum policy ; there are now distinct VCE and Frameworks statements in areas of Science, Mathematics and Technology. Technology curriculum policy documents have a historical link with technical studies in Victorian schools.

By contrast, Technology [Victoria] promotes an emphasis on technology **within** the established areas of science and mathematics subjects in a school. There is also research evidence which indicates that school students do not see a distinction between science and technology in the 'real world'. The implications are that schools would make the teaching of science and mathematics more meaningful and raise the participation of students in the subject by taking account of this perspective.

In the schools there is likely to be action on two fronts which reflect these two positions. The first is to review the emphasis on technology within established subjects in the curriculum, such as science, mathematics and physics. This might be described as an embedded approach to the teaching of technology.

The second is, where appropriate, an introduction or expansion of Technology subjects. These are subjects with a distinctive technical studies emphasis and these might be described as 'technology up front'.

Both actions will have the effect of increasing participation of students in studies with a technological emphasis, even though there may be variations in understanding of what teaching technology means.

Notwithstanding this, ways in which assistance is given to schools and teachers to incorporate a technological emphasis must be found. For example, in the embedded approach, the emphasis may be on encouraging teachers to use more technological examples in their existing science teaching repertoire. In the 'up-front' approach a major need of teachers may be the introduction of a new subject stream into an existing school curriculum.

It is our view that those associated with CAPS should be aware of these developments in curriculum in schools. CAPS sites should be clear about which of these actions they are supporting at the school level when planning and delivering their programs.

Research in Science Education 1989, 19, 13 - 24,

A LEARNING MODEL FOR SCIENCE EDUCATION

Ken Appleton

In the past, explorations of Piaget's model of intelligence have focused on the mental functioning of children (Renner, Abraham & Birnie, 1986; Posner, Strike, Hewson & Gertzog, 1982). While Piaget's ideas of assimilation, disequilibrium and accommodation have been substantiated by Renner, Abraham & Birnie (1986), there remains a problem in understanding cases where children mislearn material, and develop misconceptions (Shuell, 1987).

THE INVESTIGATION

The purpose of this research was therefore to develop a learning model which would take account of both Piaget's ideas of assimilation, disequilibrium and accommodation, and the development of misconceptions. Such a learning model could provide a powerful tool for understanding learning in science, and for guiding teaching practices. The generative learning theory (Osborne & Wittrock, 1983) was selected to combine with Piaget's theory, as it embodies ideas common to most constructivist views of learning, and overlaps with several Piagetian ideas.

THE LEARNING MODEL

The starting point for the learning model was a version of Piaget's ideas suggested by Trojcak (1979), summarised in diagram one.

The diagram presents assimilation, disequilibrium and accommodation as a desired flow-sequence for new learning, with the possibilities of existing learnings being reinforced, and of the learner opting out of learning. A detailed description of the diagram is contained in Trojcak (1979).

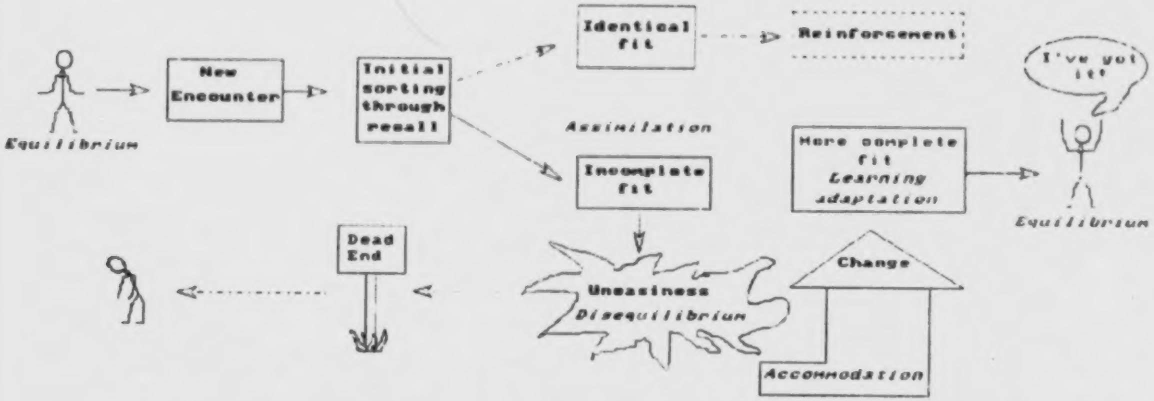

Equilibrium
New Encounter
Initial sorting through recall
Identical fit
Reinforcement
Assimilation
Incomplete fit
More complete fit
Learning adaptation
I've got it!
Equilibrium
Dead End
Uneasiness
Disequilibrium
Change
Accommodation

Diagram 1: Interaction model of learning (Piaget/Trojcak)

The generative learning theory arose, in part, from the explorations of students' misconceptions in science in the Learning in Science Project (Osborne and Freyberg, 1985). The main points of the theory are listed below, but the reader is referred to the source documents for a full explanation:

1. The learner's memory store and processing strategies interact with sensory input (stimuli of the senses) available from the environment by actively selecting and attending to some inputs and ignoring other inputs.

2. The input selected and attended to by the learner, of itself, has no inherent meaning.

3. The learner generates links between that input and those parts of his/her memory store considered relevant by the learner. Sometimes links are made to aspects of memory store not intended by the teacher.

4. The learner retrieves information from memory store, and uses this information to actively construct meaning from the sensory input.

5. The learner may test the constructed meanings against memory and sensed experience.

6. The learner may subsume constructions into memory. Sometimes new ideas may be readily accommodated alongside ideas already stored. At other times considerable restructuring of ideas and reinterpretations of experiences may be required to successfully subsume a new construction.

7. The learner will place some status on the new construction, albeit subconsciously. Frequently, new constructions and previously existing ideas in memory will be held simultaneously and over time the status of one view may increase while the other decreases.

The learning model proposed in diagram two combines elements of both theories. Comparisons of the two diagrams reveal the changes arising from the inclusion of the generative learning theory.

A learner approaching a learning task brings with him/her all previous experiences organised in the mind as sets of ideas. When a new object or event is encountered, the learner may select to attend to particular aspects of the object or event and ignore others. The learner makes sense of the object or event by drawing upon past experiences and any related explanations which seem to the learner to be relevant. If the past experiences and related explanations drawn from memory seem to satisfy all noticed characteristics of the object or event, then those memories increase in status - previous learnings have been reinforced (exit 1).

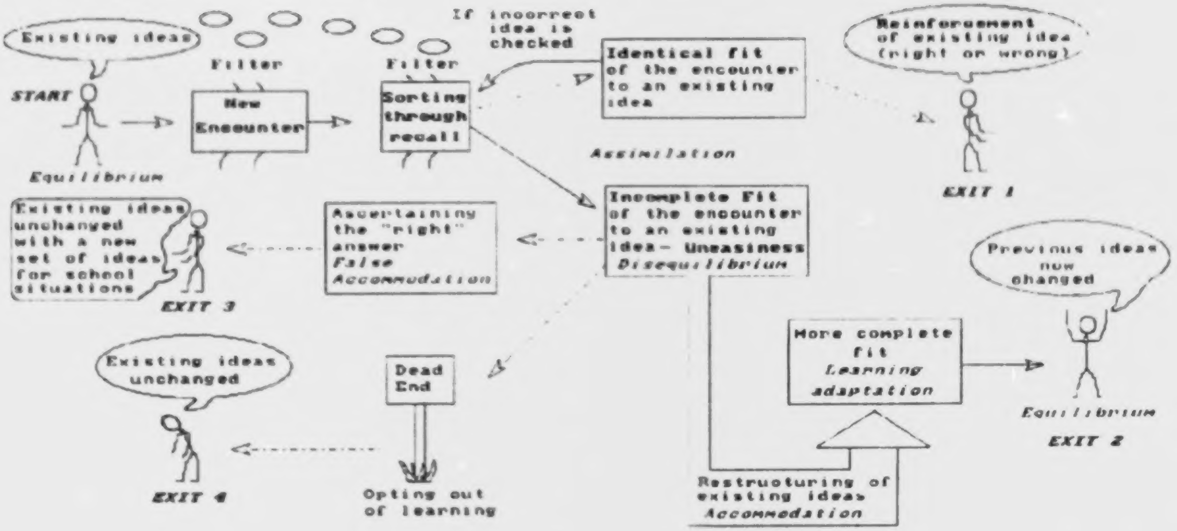

Existing ideas
Filter
Filter
If incorrect idea is checked
Reinforcement of existing idea (right or wrong)
START
New Encounter
Sorting through recall
Identical fit of the encounter to an existing idea
Equilibrium
Assimilation
EXIT 1
Existing ideas unchanged with a new set of ideas for school situations
Ascertaining the "right" answer
False Accommodation
Incomplete Fit of the encounter to an existing idea- Uneasiness
Disequilibrium
Previous ideas now changed
EXIT 3
More complete fit
Learning adaptation
Existing ideas unchanged
Dead End
Equilibrium
EXIT 2
EXIT 4
Opting out of learning
Restructuring of existing ideas
Accommodation

Diagram 2: A Learning Model

However, if the learner has not noticed some key aspects of the object or event, inappropriate sets of experiences and explanations may be used to interpret the object or event, compared to those which may have been used had those key aspects been noticed. The learner would therefore leave the learning experience with an inappropriate explanation for the object or event; a wrong explanation has been reinforced. Another problem can arise if the learner selects from memory an explanation which superficially explains the object or event, without checking for inconsistencies: near enough is good enough. In this case, a wrong idea would again be reinforced.

If the learner recognises the inadequacy of his/her memories to explain the object or event, he/she is in a state of disequilibrium, from which there are three possible exits. Exit 2 is the desired pathway, via accommodation, where old ideas are restructured to incorporate some new idea or ideas. Piaget warned of the possibility of false accommodation, which is represented by exit 3. The Learning in Science Project research identified how some children use various ploys to extract an answer from the teacher, which is often learned without understanding for testing purposes: the old ideas remain untouched, and exist side by side with a set of new ideas used expressly for school testing purposes.

A learner in the state of disequilibrium experiences some degree of frustration, the motivational force which drives a learner to seek a solution to a learning situation. However, if the level of frustration is too high, or if the effort to resolve the issue is not considered by the learner to be worthwhile, then the learner may elect to opt out. This is usually accompanied by feelings of failure (exit 4). Alternatively, a learner may choose to opt out of learning by rejecting all other available ideas - a deliberate rational choice.

A learner who follows the pathway to exit 2 could experience an overload of information, and have difficulty constructing scientifically accurate explanations which endure over an extended period of time (Gauld, 1988). Parts of ideas may be misremembered, or rationalised to conform to the final explanation accepted by the learner. Misconceptions could therefore be constructed at the time of accommodation, or some time later.

THE EVALUATION

The above learning model for conceptual change was evaluated by examining a series of learning situations, and exploring the explanatory power of the model. The learning situations typically involved mixed groups of eleven to twelve year olds, in groups of two to four. All children were from mixed ability urban schools. The teaching sequence followed the same basic pattern each time, except where it was deliberately varied to test a particular aspect of the learning model. Each group of children worked with a teacher on the same topic, "Floating and Sinking", using an activity-oriented approach. The activity was taught as one lesson, with follow-up interviews a fortnight later. Initially, the teacher variable was kept constant by the author working with each group, but this was later extended by tutoring student teachers in the lesson steps, and assigning them to work with groups of children. Six groups were taught by the author, and ninety-five by the student teachers. Groups were observed closely as they worked, and both verbal and written reports by the student teachers were analysed.

RESULTS OF THE EVALUATION

In the section which follows the general patterns of responses by the children have been documented, with specific examples where appropriate. A brief indication of the teaching steps has also been included to provide a context for the discussion.

The new encounter and assimilation

The learning experience commenced with the children being given a number of objects to predict whether they would float or sink. The objects were then tested in a basin of water. When making predictions, children relied heavily on specific things which they remembered would float or sink, and generalisations were frequently made on the basis of these remembered events. Most children remembered, for example, that foam plastic (expanded polystyrene) floated, and some generalised to include all plastic. Some children remembered about apples floating, from party games; others admitted not knowing whether an apple would float. Some remembered that potatoes sank, because they helped around the kitchen at home. However, a few were convinced that the potato would float, citing as evidence their recollection of pieces of potato "floating" when french fries were cooked. A few children persisted with this view even after observing the potato sink.

The influence of existing ideas acting as a selection mechanism was evident, for example, where children worked from the generalisation that plastic floats. They selected objects on the basis of whether they looked like plastic, and ignored other characteristics. The children who insisted that potato floats ignored everything else while they attempted to get the potato to float.

Since the apple and potato attracted much attention, the focus of the remainder of the activity was directed towards these: the children were asked to explain why the potato sank and the apple floated. The children retrieved explanations from memory in response to the question. Ideas about the apple included:

"It has air in it - around the seeds. It's floating 'cos it's got air in it."

"The skin won't let the water in."

"It's light; it floats 'cos it's light."

Ten percent of responses by the children included some mention of density, or used some intuitive explanation of density:

"The stuff in the potato is packed in more tightly than the stuff in the apple."

Very few children attempted to invoke Archimedes' principle, and none of those who did were able to explain it satisfactorily; they struggled to remember something that had perhaps once made sense when they had read it, but was now difficult to recall.

The process of assimilation, then, quite clearly involved attempts to fit information into existing ideas, and examples of the selection process of ideas on what the children observed and did were noted.

Exit one, an idea reinforced

As indicated above, a variety of ideas emerged in the children's attempts to explain why the potato sank and the apple floated. If the teacher left the children to their own devices and did not intervene, the children invariably closed the issue fairly quickly. An answer was accepted as "the answer", and this idea was accepted by all or most of the children: an existing incorrect idea was reinforced for most children. The process of accepting an answer followed one of two pathways::

(i) The explanation proposed by the child acknowledged by the others as clever, was accepted unquestioned.

(ii) An informal vote was held, where children apparently stated their affirmation of the idea that made most sense to them. Occasionally a dispute over two ideas would remain unresolved, with the parties agreeing to disagree.

When the teacher intervened, the type of intervention determined what would happen next. If there was any confirmation about an idea, the children closed the activity, with the confirmed idea reinforced as correct by the teacher-authority figure. If the teacher remained non-committal, and demanded proof of the idea in question, the children readily devised and conducted tests for the idea, when the teacher encouraged them to do so. For example, the children in one group considering the idea about the apple skin being waterproof, decided to remove the skin, "so the water can get in."

It was established in the early trials of the teaching sequence that little new learning would occur if the teacher did not intervene. It was estimated that around ninety-five percent of the children would have left the activity with a wrong idea reinforced, had the teacher not intervened.

Exit three, false accommodation

Not all children suggested an explanation as to why the apple floated and the potato sank. Even if asked for an idea, some would hedge, plead ignorance, or repeat an earlier response by another child. If asked first, they would rarely provide an answer. Thirty to forty percent of the children tended to do this. It may have been that the children genuinely did not know a reasonable explanation, but they tended to be quick to seize upon any indication that the teacher or a clever child preferred one idea over another. For example, in some groups, the teacher repeated ideas suggested by the children, to seek confirmation that the idea was understood:

"So you think the skin is waterproof. The water can't get in?"

such statements were interpreted by a few children as a confirmation of the idea, and agreed with it. When that idea had been demonstrated false, and another idea proposed and apparently confirmed by a similar statement, they agreed with the new idea. This happened three times with one child, and four times with another.

Even when an acceptable answer was proposed and tested, these children merely repeated words, but could not explain or justify them. The extent of false accommodation was difficult to ascertain, as some of the children who sat back waiting for an answer also tried to accommodate the idea finally accepted by the group of children. For example, some asked questions to gain a better understanding of the idea, and appeared to attain a fair grasp of it.

Exit four, opting out

A very small number of children, perhaps two percent, did not participate beyond the initial encounter. One was a child who insisted that a potato would float, and would not accept evidence to the contrary.

Fifteen percent of the children were observed at some stage to withdraw from the activity when progress towards "the answer" seemed slow. This tended to occur after several of the children's ideas were tested and demonstrated false. No new ideas were evident to the children, so they gave up. This happened earlier in the activity for some children than for others. However, almost all of the children were drawn back into the activity with appropriate action by the teacher. Only three percent could not be involved satisfactorily in the activity again. Such children displayed typical non-participatory behaviours such as sitting back from the others, avoiding giving responses, and gazing around.

As noted in the next section, some children appeared to have reached accommodation at the time, but later experienced some difficulties in that they could not recall an adequate explanation, or they reverted to an earlier idea previously dismissed. An unknown number of these children may have experienced failure because of this.

Exit two, accommodation

When a child proposed an idea about relative density, the idea was subsequently tested. This in itself was not easy, as the teacher usually had to help devise a test, and reliable tests easy to conduct were not obvious. In fifteen percent of groups, a suitable idea about density came from one of the children. For the remainder, the teacher provided an explanation, which was then tested. From earlier trials, the explanation most acceptable to children was found to be the one put forward spontaneously by children:

> "The stuff in the potato is packed in more tightly than the stuff
> in the apple."

This phase of the activity demonstrated the complex nature of the process of accommodation. Although accommodation is a process internal to the child, only a small number of children were able to restructure ideas to include a new (correct) one without assistance. Like a new day dawning, a new idea suddenly occurred to some children; but most had to have the new idea explained to them by the teacher or another child. Often, the explanation had to be made more than once, and had to be accompanied by exploratory activities comparing densities; for example, noting floating height in salt water, cooking oil, and methylated spirits.

Problems in accommodation were also observed. Twenty percent of the children could not really understand the new idea at all. It was subsequently rejected, and an earlier idea resurrected with modifications. For instance, the popular idea of the apple floating because of air around the seeds, was modified to air being between the cells in the fruit, causing it to float:

> "They're (the cells) like footballs all packed together, with spaces between. That's where the air is."

A likely cause of the problem for these children was documented by Hewson and Hewson (1983), in that the explanation was not intelligible, plausible and useful. Some children, possibly five to ten percent, concluded the activity with no solution which they both understood, and were satisfied with. Another twenty percent of the children appeared to understand the new idea at the time, but had difficulty fitting it into existing ideas. In a follow-up interview a week later, these children had considerable difficulty explaining the new idea.

Within the limits of producing figures from this kind of evaluation, indications of outcomes and learning model exits gauged from both the activity and the follow-up interviews were as follows:

Exit 1	-	reinforcement of an idea, some correct, some incorrect	30%
Exit 1	-	accommodation, though some children later had difficulties	45%
Exit 3	-	false accommodation, a verbal answer with little understanding	20%
Exit 4	-	opted out of learning, and were not retrieved	5%

CONCLUSION

It was thought that the evaluation substantiated the various steps in the learning model as a reasonable description of cognitive learning in this activity. Each of the postulated exits and problem areas associated with them as noted. Informal observations of children working with other topics suggest that the model may be generalisable beyond this activity and the teaching steps used in it. However this needs to be substantiated.

Caution should also be exercised in putting too much reliance on the percentages quoted above. The children worked in groups, and it was sometimes difficult to analyse what each child was thinking, and the degree of influence the children may have had on each other. Furthermore, most of the activities were conducted by student teachers where some differences in their ability to interact with the children and explain ideas were noted. In fact, a key aspect as to how well the children understood the new idea presented to them appeared to be related to how well the student teacher understood it him/herself.

Since the steps in the learning model seem to have some validity, they may also give rise to particular teacher interventions which facilitate progress through the learning model. If such interventions are identifiable, they may provide guidance for teachers in selecting appropriate teaching strategies.

REFERENCES

GAULD, C. (1988). The cognitive context of pupils' alternative frameworks. International Journal of Science Education, 10, 267-274.

HEWSON, M. & HEWSON, P. (1983). Effect of instruction using students' prior knowledge and conceptual change strategies in science learning. Journal of Research in Science Teaching, 20, 731-743.

OSBORNE, R. & FREYBERG, P. (1985). Learning in Science: the implications of children's science. Auckland, Heinemann.

OSBORNE, R. & WITTROCK, M. (1983). Learning science: a generative process. Science Education, 67, 489-508.

POSNER, G., STRIKE, K., HEWSON, P. & GERTZOG, W. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. Science Education, 66, 211-227.

RENNER, J., ABRAHAM, M. & BIRNIE, H. (1986). The occurrence of assimilation and accommodation in learning high school physics. Journal of Research in Science Teaching, 23, 619-634.

SHUELL, T. (1987). Cognitive conceptions of learning. Review of Educational Research, 56, 411-436.

TROJCAK, D. (1979). Science with Children. New York, McGraw-Hill.

Research in Science Education 1989, 19, 25 - 36,

THE ALTERNATIVE CONCEPTIONS OF A PARTICLE THEORY OF AIR POSSESSED BY YEAR 1 - 5 PRIMARY STUDENTS, THEIR PARENTS, AND THEIR TEACHERS.

Howard H. Birnie

INTRODUCTION

It is now generally accepted that students come to science class with pre-formed concepts and understandings about the phenomena they are to begin to study. These ideas, called preconceptions or alternative conceptions, result from the variety of previous experiences and communications children and youth have.

Study after study has reported that these ideas seem to make sense in the world view of the student and that they are remarkably resistant to modification or extinction.(See for examples Osborne and Freyberg, 1985; and, Driver, Guesne, and Tiberghien, 1985).

Driver, Guesne, and Tiberghien (1985) describe these pre- conceptions, intuitions, or conceptual primitives as personal in nature, seemingly incoherent, and stable. They also believe that " although there is a variety in the ideas children use to interpret phenomena, there are clearly some general patterns in the types of ideas that children of different ages tend to use ".

The research in this field is now concentrating on clarifying and developing taxonomies of the common misconceptions in each science topic, and vigorously examining teaching strategies which are effective in encouraging students to re-think their alternative conceptions. The former is in the spirit of Kuhn's normal science (1962).

This study, however, continues the research in one of the more essential, yet difficult areas of conceptual development, kinetic- molecular theory, as revealed through concepts related to air pressure.

In the present study, three kinds of comparisons are made. First, a cross- age study will attempt to follow the formation of alternative ideas and concepts from age 6 (year one) to age 18 (year twelve) of kinetic molecular theory as it applies to air pressure and related ideas. Second, the opportunity to interview subjects in Australia, New Zealand, and Canada will allow a cross-cultural comparison. Finally, the unique contribution of this study will be the comparison of working knowledge of these concepts among students, their teachers, and their parents. In this first report, the results of the work with these three groups in Australia and New Zealand are considered.

RELATED RESEARCH

The early research reported here from previous studies focusses mainly on students in the intermediate or middle years (or junior high school).

In a study in 1978 with 14 year olds in Israel, Novick and Nussbaum found, among other results, that only 40 % of the sample believed in intrinsic motion and chemical combination by particles, and only 35 % decisively believed in space between particles. The alternative model advanced by the students was of matter conceived as basically continuous and static. The aspects of the particle theory which were least assimilated were the vacuum concept, intrinsic motion, and interaction between particles.

Employing a written test of similar questions with elementary to university students in the United States, Novick and Nussbaum (1981) found similar results. In addition, they concluded that the percentage of students who provided elements of scientifically accepted ideas increased with age, and that with several concepts there was no increase beyond the junior high school level.

As part of a national survey project in England with 300- 15 year olds, Brook, Briggs, and Driver (1984) reported the following findings:

(1) 50 % used particulate ideas

(2) 20 % of all students, and 33 % of those studying physics and chemistry, gave explanations using particles

(3) One in three students used alternative particle ideas

(4) One in four students gave macroscopic responses with no mention of particulate ideas.

In a further experiment using the case study approach to get at the dynamics of conceptual change of 12 year olds in New York, Novick and Nussbaum (1982) concluded that " students do not easily give up their preconceptions and that they tend to assimilate new information into their previous conceptions, constructing a mixed conception".

Osborne and Schollum (1983) concluded that only about 20 % of Form 3 to Form 5 (years 8 to 10) pupils in New Zealand consider there to be nothing between particles.

Brook and Driver (1989) reported a cross- age study of pupils' ideas about air in the Children's Learning in Science Project in Leeds. Some of their conclusions are pertinent to the present study.

1. By age 12 most pupils will say that air contains oxygen and by 16 about half indicate that air is a mixture of gases.
2. About a third of five year olds recognize air occupies space and this idea was quite well developed in the majority of eight year olds.
3. About a third of all pupils aged 16 recognised that air can transmit force in all directions.
4. Air seems to float around rather than press down. The idea that air has weight is held by a quarter of the 16 year olds.
5. Children identify a suction force as needing air through which to act. By age 12, students use the idea of vacuum. Only a third of 16 year olds referred to air pressure or pressure differences producing observed effects.

THE STUDY

Purpose

The purpose of this study was to attempt to trace the development of ideas of the kinetic- molecular theory as it applies to air pressure in students from age 6 (year one) to age 18 (year twelve). In addition, in order to determine the level at which adults function in using these concepts and to identify some of the factors which may influence this conceptual formation, teachers and parents of the students were given the same questions. A second purpose for the study was to collect the misconceptions held by the respondents for use by teachers.

Methodology

The one-to-one interview method was used throughout this study. All interviews were conducted by the author. Interviews were arranged in the school, although some were conducted in the homes of the parents.

Interview Instrument

The interview protocol consisted of twelve basic questions, the answers to which were pursued for as complete an understanding as was possible essentially of the aspects of particle theory outlined by Novick and Nussbaum (1978), and other concepts related to air pressure as defined by Brook and Driver (1989). These are outlined later in the paper. The twelve questions are included in Table 1, which also presents a list of the misconceptions held by the respondents.

Table 1

Particle theory and Air Pressure Interview Questions and Results: Misconceptions Held

1.What does the word air mean to you ?

Students -It's colder in air than in space (1)
-Flowers make air (1)
-Air is cloudy (2)
-Air is gravity (2)
-Air is moisture and fog (5)
-Air is oxygen (5)

Parents -Air is a chemical
-Air is energy

2Do you think air has weight ? Why ?

Students -No, because you can't eat it (2)
-Martians breathe CO_2 and don't have air (3)
-Air is light and goes up (5)

Parents -If air has moisture in it will have weight
-If you add air to something,it doesn't change weight

3.Do you think air takes up space ? Why ?

Students -Air goes down to the ground and blows itself (1)
-Water is air; you can see it on glass in the morning(5)

4.What does the word wind mean to you ?

Students -Wind puts out fire (1)
-Wind is oxygen (3)
-Air comes from plants (3)
-Wind comes from clouds and the sea (4)
-Trees make wind blow (5)

Parents -Wind comes from the clouds
-Earth's magnetic field causes winds
-Waves of the ocean cause winds
-Wind depends on the moon, tide and seasons

5.Why do you think a balloon gets bigger when you blow into it ?

Students -Air gets fatter (1)
-Because the air wants to get in there(2)
-Wind makes it get bigger and hotter (3)
-Oxygen from your mouth makes it bigger (5)

Parents -When you blow in a balloon it rises
-Air gets pressure from the lungs.

6.Why do you think they put air in car tires ?

Students -

Parents - Tires lose air all the time
- Hot air produces the cushion
-Air counteracts the rubber
-Air allows the tire to breathe, so it doesn't harden

7.If you open a bottle of perfume near one side of a room, can you sometimes smell it on the other side Why ?

Students -Air goes in the bottle and picks up the perfume(5)

Parents -Essence escapes and the smell just spreads
-Air acts like a sponge sucking up the fumes

8.Inverted beaker demonstration: What will happen in the inverted beaker ? How do you explain what is happening ?

Students -The water gets bigger (2)
-The cork kept the water out by floating (5)

Parents -Air forms a vacuum
-Gravity keeps the water out
-Water levels will be equal inside and out
-Water has a skin on it and air cannot pass through

9.Soft drink bottle demonstration : When youuse a straw, how do you think the drink gets up the straw ?

Students -Breathing brings the water up (5)

Parents -A vacuum draws the water
-Air from your mouth draws thewater

10.What does the word space mean to you ?

Students -Space is a different country (1)
-Planets are floating in the air (1)

Parents -There is no gravity in space
-Space is air without oxygen
-There is atmosphere between planets
-Space is outside our gravity

11.What do you think is meant by the word gravity ?

Students -Gravity can burn a rock, my dad told me (1)
-Gravity is soil and rocks (1)
-Comes from the crust (2)
-No gravity in space, so you float (5)
-Gravity comes from the moon (5)

Parents -There is no gravity in space
-Gravity pulls against a vacuum
-Gravity is caused by the movement of the planets
-Gravity is caused by the turning of the earth
-Created by centrifugal force
-A magnetic force related to the density
-Gravity comes from the planets

12.What do you think is meant by the word vacuum ?

Students -Vacuums have air in them (3)

Parents -Vacuums absorb with a force of air

The questions were field-tested on 300 students from ages six to twelve in Saskatchewan, Canada, and validated by a panel of science students and educators. A detailed interview report check list was devised based on the responses of the trial group. It was found that the efficacy of the check list, which went through several revisions, allowed the interviewer time to write down pertinent quotations from the subjects and as a result the decision was made not to tape record. Interviews generally took from 10 to 15 minutes to conduct. In questions 8 and 9, participants were shown demonstration apparatus.

Subjects

In the research reported here, interviews were conducted in 2 schools in Australia, and 3 schools in New Zealand. Random sampling was not employed. Teachers were requested to choose students of average or near average achievement. School A was a small independent urban elementary (or primary) school in West Australia, descibed as located in a middle-class socio-economic district, with students described as of average achievement. School B was an independent secondary ladies college. The New Zealand schools serving middle-class socio-economic districts were all located in an urban setting. School C was an elementary normal school, School D an intermediate normal school, and School E a senior high school. In all there were 164 respondents, consisting of 103 students, 43 parents, and 18 teachers.

RESULTS

Comparative Scoring

The interview records were examined, first, for the match between the concepts held by the subjects and the presently accepted theory and concepts held by scientists. To facilitate comparisons, a 5- point marking scheme was used to award credit to the interview responses. Thus, the decision was made to combine a quantitative measure with the richness of the interview dialogue. The categories for awarding credit were as follows:

1- point: misconceptions; concepts have little or no meaning

2- points: uses descriptive terms to describe the object under discussion and its behaviour

3- points: concept partially developed

4- points: increased or intermediate understanding of the concept

5- points: as a scientist understands it.

Notice that the scoring system guaranteed a minimum score of 12.

The boundaries of the questioning, that is, where to stop asking, were taken from Novick and Nussbaum (1978) as they pertain to the particulate model of gases. The attributes follow:

1. A gas is composed of invisible particles
2. Gas particles are evenly scattered in any enclosed space
3. There is 'empty space' between the particles in a gas
4. Particles of a gas are in intrinsic motion, even when they are not pushed externally
5. When two different gaseous substances interact to form a third substance, we picture this as the joining together of different kinds of particles.

In this study, only peripheral use was made of attribute 5 above. Questionning pertaining to properties of air were halted when exploration of the children's ideas had reached those used by Brook and Driver (1989) as stated below:

1. air is all around us;
2. air spreads out to fill available space;
3. air has weight;
4. air can be compressed and expanded;
5. air around us exerts a pressure (even in equilibrium);
6. air pressure acts equally in all directions;
7. pressure differences tend to equalize; and,
8. air is necessary for life.

An outline of the scoring key is presented as Table 2.

Table 2

Scoring Key for particle theory as it is revealed by air pressure questions

Questions	1 misconceptions; little or no meaning	2 description of object or behaviour	3 concept partially developed	4 as an adult non- scientist understands it	5 as a scientist understands it
1. What is air ?	DK; air is clouds	cold; air is wind feel air; everywhere air moves	air is oxygen; we breathe air; invisible	air is a gas; made up of particles;	mixture of gases; atoms and molecules space between
2. Does air have weight ?	DK; wrong answer-no explanation	right answer-no explanation	full of molecules; learned in school	all matter has weight	atoms and molecules have mass andweight
3. Does air take up space?	DK; wrong answer-no explanation	right answer-no explanation	balloons get bigger; invisible so it seems not to take up space	it is matter,therefore it takes up space	particles have mass and weight,therefore take up space
4. What is wind and cause?		cold; blows; wind is air	moving air; force	moving air or force; partial cause	moving air caused by unequal heating
5. Balloon expansion		You blow or breathe more air in it	air becomes confined; air expands	air pressure	bombardment of moving molecules
6. Car tire expansion	drive easier;	air cushion; doesn't go flat; tire bigger	air becomes confined; air expands	air pressure	bombardment of moving molecules
7. Perfume diffusion.	Yes or no; no reason	nose pulls it in	air blows it; smell floats in air	perfume vaporizes; air currents carry it	molecular motion of perfume vapour
8. Inverted beaker demo.	Air bubbles out; incorrect answer	water will fill inverted beaker;	water will rise part way; air pressure	water does not rise; air keeps it out	Water does not rise; pressurequilibrium
9. Straw demonstation	you drink it	draw it up with your mouth	suction draws all the air and water out	vacuum created by suction; drink pulled up	Atmospheric pressure
10.What is space ?		darkness; air stops with atmosphere	outer- moon,planets, etc.;	all objects occupy space; outer space;	all objects occupy space; vacuum in space between
11. What is gravity ?	DK; comes from your body	keeps you on the earth	holds you to the earth; comes from earth	A force between all objects	A force between all masses; depends on separation
12. What is a vacuum ?		A machine which sucks in dirt or air	empty space	air is removed	devoid of all matter; may be partial

A second purpose for examining the responses was to collect the misconceptions held by the respondents for comparison purposes. The list of misconceptions identified is presented as Table 3. Separate listings of the misconceptions held by students, parents and teachers are included.

The Findings

Table 3 presents the comparison of scores of students, parents, and teachers in the five schools.

As Table 3 shows, the scores generally increased linearly with age and grade. The scores of comparable age groups in the two elementary schools are similar. For example, Grade S1 (mean age 7.6 years) in School C in New Zealand is similar to Grade 3 (mean age 7.3 years) in School A in Australia. The one anomaly in the mean scores, 30.6 for the Grade S3 in School C, could be explained by the fact that they had just completed a unit on air a few days before the interviews.

Comparison of Forms 4 to 7 from School E in New Zealand with Grades 9 to 12 in School B from West Australia demonstrate parallel performances by these secondary students. Deviations from linearity were usually due to one score in the small samples varying somewhat from the others.

The teachers in the two elementary schools were not science specialists. The two mean scores, 35 from School A and 35.8 for school C, were similar. The two higher scores of the five teachers in School A were made by recent graduates of teacher education who were in only their second year of teaching. The mean scores of the science teachers in the elementary schools A and C were slightly lower than the mean scores of the parents who did not have university degrees, while scores for science teachers in Schools D (intermediate) and E (secondary) were considerably higher.

Mean scores for parents without university education from Schools A (35.9), B (36), C (36.7), D (33.5), and E (35.5) are remarkably similar. Mean scores for parents with university degrees from Schools B, C, and E are considerably higher.

Table 3: Comparison of mean scores of students, parents, and teachers for five schools in Australia and New Zealand.

AUSTRALIA

School A (Primary)	Grade	N	Mean Age (Years)	Mean Score
Students	1	5	5.9	18.6
	2	5	6.4	18.6
	3	5	7.3	20.4
	4	5	8.7	23
	5	5	9.7	24.2
Parents (Univ.)		2		50
Non-Univ.		15		35.9
Teachers		5		35
School B (Secondary)				
Students	9	6	14.1	33.2
	10	5	14.8	46.8
	11	6	15.9	47.3
	12	5	17	53.8
Parents (Univ.)		4		46.3
Non-Univ.		1		36

NEW ZEALAND

School C (Primary)	Grade	N	Mean Age (Years)	Mean Score
Students	J2	5	6.8	20
	S1	5	7.6	21.2
	S2	5	8.2	21.2
	S3	5	9.7	30.6
	S4	5	10.6	24
Parents (Univ.)		4		57.3
Non-Univ.		10		36.7
Teachers		5		35.8
School D (Intermediate)	F1	6	11.8	30.8
	F2	6	12.6	31.3
Parents (Non-Univ.)		4		33.5
Teachers		5		42.8
School E (Secondary)	F3	3	13.3	
	F4	4	14.8	
	F5	4	15.7	
	F6	4	16.4	
	F7	4	17.9	
Parents (Univ.)		1		55
Non-Univ.		2		35.5
Teachers		3		58.3

Interpretations of the findings from other researchers

Other researchers have attempted to interpret student's responses to questions relating to particle theory. Part of the analysis in this study was based on their categorizations.

Nussbaum (1985) attempts to categorize students' difficulties with the concepts, theoretical constructs, and metaphysical assumptions of the particulate nature of matter in the gaseous phase. He identifies these as:

(1) Animism- relating animal characteristics to non-living objects;

(2) Natural place- substances moving toward their natural place; (3) Vacuum is impossible; rejects interaction between two material bodies for a perceptually- based "sucking" force theory; and,

(4) Difficulty internalizing the idea of empty space.

Driver, Guesne, and Tiberghien (1985) identify some general features of children's thinking within a framework of alternative conceptions.

(1) Children employ perceptually dominated thinking rather than construct models using entities which interact.

(2) Children interpret phenomena in terms of limited focus on the absolute properties of objects rather than interaction between them.

(3) Changing conditions require an explanation; conditions in equilibrium don't.

(4) Children reason from cause to effect linearly, ignoring reversible and reciprocal events.

(5) Some ideas held by children related to one concept are more inclusive and global than those of scientists.

(6) Children often call upon different ideas to interpret situations which a scientist would explain using the same ideas.

Conclusions and Interpretations of data in this study

Some tentative conclusions are advanced as working hypotheses based on the limited sampling thus far in the study.

1. There is no indication of use of a particulate nature of matter in the explanations of children from years 1 to 5, although the words "atoms" and "molecules" have been mentioned by a few.

2. Parents without a university education and elementary school teachers score equally well on the questions, those scores being very similar to Grade 9 and Form 4 performance. Part of the explanation for this performance level lies in the fact that science methods are not compulsory in some teacher education programs.

3. Almost all respondents used the "sucking" force theory to explain the rise of liquids through a straw, not one identifying the interaction involving the pressure of the atmosphere and Pascal's Law of pressure transmission. This would be described by Piaget's "centering" or observations which are perceptually dominated.

4. Considerably better scores are made by those parents who have a university education involving some science and who are usually employed in vocations where they make use of the concepts touched on in the questionnaire.

6. The interpretations of Nussbaum (1985), particularly the use of animistic explanations, are emerging.

7. The general features of children's thinking summarized by Driver, Guesne, and Tiberghien (1985), particularly perceptual domination, ignoring interaction effects, and the use of global ideas as opposed to specific ones, are being confirmed.

8. The responses of the children up to 10 years old are similar to those reported by Brook and Driver (1989), with respect to air containing oxygen, and air occupying space, but the idea of vacuum was confined to the vacuum cleaner.

IMPLICATIONS FOR TEACHING

The results of this study based on limited numbers not randomly selected support what constructivists have been saying about the wide variety of alternative conceptions and misconceptions held by students. It is essential that teachers be aware of these before beginning a new science topic and that science teaching give some attention to restructuring them.

The idea that matter has a particulate nature is complex and abstract, and is not likely to be arrived at by many persons through their own inquiry. Schools have a major responsibility here through the science programs to introduce these ideas wisely.

The finding in this study that primary or elementary teachers, parents without a university degree, and Grade 9 (Form 4) or lower students, think at the same conceptual level about kinetic molecular theory as revealed through air pressure, should be of serious concern in an age of science and technology and certainly should have some relevance for teacher education. In addition, the question of how much science a person who is not going on to higher education requires should be the focus of further study.

REFERENCES

BROOK, A., BRIGGS, H. & DRIVER, R. (1984). Aspects of secondary students' understanding of the particulate nature of matter. Children's Learning in Science Project. Centre for Studies in Science and Mathematics education, The University of Leeds.

BROOK, A. & DRIVER, R.(1989). The Development of Pupils' Understanding of Physical Characteristics of Air, Across the Age Range 5-16 Years. University of Leeds, Children's Learning in Science Project.

DRIVER, R., GUESNE, E., & TIBERGHIEN A. (Eds) (1985). Children's Ideas In Science. Philadelphia, Open University Press.

HAPPS, J. (1980). Particles. University of Waikato, The Learning in Science Project.

KUHN, T. (1962). The Structure of Scientific Revolutions. Chicago, University Press.

NOVICK S. & NUSSBAUM, J. (1978). Junior high school students understanding of the particulate nature of matter: an interview study. Science Education, 62(3), 273- 281.

NOVICK, S. & NUSSBAUM J. (1981). Pupil's understanding of the particulate nature of matter: A cross age study. Science Education, 65(2), 187- 196.

NUSSBAUM, J. (1985). The Particulate Nature of Matter in the Gaseous Phase. In Children's Ideas in Science, Eds R. Driver, E. Guesne, & A. Tiberghien. Philadelphia, Open University Press.

NUSSBAUM, J. & NOVICK, S. (1982). A study of conceptual change in the classroom. A paper presented to NARST annual meeting, Lake Geneva, USA.

OSBORNE, R. & FREYBERG, P. (1985) Learning in Science: the implications of children's science. Auckland, Heinemann.

OSBORNE, R. & SCHOLLUM B. (1983). Coping in Chemistry. The Australian Science Teachers Journal. 29 (1), 13- 24.

Research in Science Education 1989, 19, 37 - 46.

STUDENT NOTE-TAKING IN CHEMISTRY LECTURES

R. B. Bucat and G. Williams

INTRODUCTION

The principal medium of science instruction at the first-year level in most Australian tertiary institutions has always been the lecture. Despite this, relatively little research has been conducted on the nature and efficiency of processes occurring during lectures.

Oft-heard comments from lecturers ("But they should know that - I told them in last week's lecture".) suggests that the complexity of the lecture is not universally appreciated. The lecture cannot be regarded as a simple transfer of information from expert to novice, and neither is it valid to expect that all students arrive at the same degree and quality of understanding. This is apparent if one analyses the processes that occur in relation to each piece of information presented during a lecture. At least the following processes are involved:

- Over time, the lecturer will have developed a unique understanding of the "public knowledge" (West, Fensham and Garrard, 1985) that constitutes the course content.
- The lecturer uses signals (such as verbal statements, blackboard notes, demonstrations, etc.) designed to convey this knowledge effectively.
- The students visually or aurally receive some or all of the signals, depending upon their mental alertness and motivation, as well as on the quantity and clarity of the signals.
- Some of the signals are interpreted in the students' working memories and relevant notes may be recorded.
- An interpretation (probably unique to each student) of some of the signals is stored in the students' long-term memories.
- At a later time, students read their lecture notes and, as a result of further processes of interpretation and sense-making, possibly in conjunction with other learning activities, develop new understandings.

As a first step in investigating lecture processes, this research has developed a method to assess the degree of correspondence between students' notes and (i) the signals of various types used by the lecturer, and (ii) the ideas that the lecturer attempts to convey.

Hartley and Davies (1978) report two main reasons why American and British students take notes: they believe that the process of writing notes will help their subsequent recall and that the products (their lecture notes) will be useful for later revision.

Most studies into note-taking were conducted prior to 1980 and in many cases the conclusions are in conflict. For example, Stanton (1976) found no significant difference between students' notes when information was presented using either slides or blackboards. On the other hand, according to Hartley and Cameron (1967) and Maddox and Hoole (1975), information presented in slides is unlikely to be recorded by students.

A more fundamental weakness in previously published work, except for that of Hartley and Marshall (1974), is that the method involved an artificial context in that (i) the lecture topic was irrelevant to the audience, (ii) the lecture was "one-off", rather than one of a series, (iii) the information was presented via a film or a tape recording, (iv) the duration of the lecture was much shorter than the standard university lecture, or (v) students were instructed whether to take full notes, brief notes or no notes - regardless of their personal styles.

Howe (1975) criticised naturalistic studies because "global comparisons of this kind do not provide adequate control for a number of important variables" although Howe and Singer (1975) recognised that it may not be possible to extrapolate results from artificial studies to processes in real lectures.

The present researchers accept that uncontrolled variables in a naturalistic setting will limit the generalisability of findings. However the main thrust of this work is not to produce generalisable results so much as to develop a method that will allow individuals to investigate note-taking processes in their own lectures. Some results reported in this work may provide useful guidance for such investigations.

The method developed in this work is intended to allow lecturers to find answers to questions such as the following:

1. How comprehensive are students' notes? What characteristics govern whether or not they record notes related to any particular idea?
2. How accurate are students' notes? What sorts of inaccuracies are most common? Why?

No attempt was made at this stage to investigate important issues such as the amount and quality of learning that takes place during lectures or the ways in which students use their lecture notes to assist learning.

THE CONTEXT

This investigation was restricted to lectures of 45 minutes duration in the mainstream first-year course in the School of Chemistry at the University of Western Australia in 1988. Lectures were given to 160 students in a theatre with a capacity for 260. The course consisted of 80 lectures, divided into four approximately equal segments given by four different lecturers. The lectures were traditional in style in that they were content-based, lecturer-controlled and lecturer-dominated. No attempt was made to control the behaviour of lecturers or students.

Student records were inspected after each of four lectures (one from each lecturer), the content of which is summarised as follows:

A. Organic chemistry: nomenclature, bonding in benzene.
B. Physical chemistry: thermochemistry.
C. Inorganic chemistry: bonding, crystal structures.
D. Physical chemistry: colligative properties.

METHOD

Lecturer-Researcher Trust

The cooperation of lecturers could not be expected without minimisation of threat to them, so the request to the lecturers to participate in this project was framed as an invitation to learn about the processes occurring in their lectures. Consequent to this, it was absolutely essential to develop and maintain a trust that assessment of the lecturers was not a component of the project and that video and audio records of the lectures would be confidential.

Records of Lecturers' Signals

For all 80 lectures of the course, a video camera and operator were positioned at the rear of the lecture theatre before the students entered. The first lecturer made a general statement concerning a member of the staff carrying out a research investigation, and no further reference was made to the presence of either the camera or the operator. Students very quickly came to ignore them.

The video camera tracked the movements of the lecturer so that all signals were recorded. These included verbal comments, blackboard writing and diagrams, overhead transparencies, demonstrations, slides and models. A tape recorder was placed on the lecture bench to support voice recordings.

A transcript was made of the verbal signals and this was annotated with the blackboard signals at the appropriate points, as well as with codes to indicate times of either high or low voice emphasis.

The videotapes were used to replicate the blackboards on paper, and the board notes were divided into separate signals.

Information Units

For the purpose of assessing the degree of correspondence between the students' notes and the information which they needed to process, it was convenient to define information units, each being a singular, distinct piece of information or idea that the lecturer attempted to convey to the students by means of various signals. These were inferred from the signals used by the lecturer and validated by each lecturer with the aid of the lecture transcript.

There is not a 1:1 correspondence between the information units and the lecture signals. For example, two verbal signals and a blackboard signal may be used to attempt to convey one information unit. The following are examples of information units inferred from signals used during a lecture on crystal structures:

1. To consider packing arrangements in three dimensions, one can take close-packed arrays in two dimensions and lay them on top of each other.
2. The hole formed when a two-dimensional hexagonal array of atoms is placed over another two-dimensional hexagonal array such that the atoms of the second layer lie in hollows of the first layer is called a tetrahedral hole.

Some information units were organisational, rather than chemical. The following are examples:

1. On this slide is a representation of the packing of chlorine molecules.
2. Now let's consider ionic compounds with a very small radius ratio.

Although definition is difficult and identification is judgemental, each information unit is a separate idea which students had to mentally process to make sense of a lecture.

Collection of Students' Notes

It was necessary to collect students' notes on the same day as the lecture because of the likelihood that some students would annotate or modify their records that night. Eighty of the students in lecture A had a laboratory class the same afternoon. During this class the students were asked to provide their lecture notes and the 56 sets obtained were photocopied and returned. At the end of each of lectures B, C and D a list of 20 students, obtained randomly from the enrolment register, was shown on a slide and those named were requested to stay behind. These students were asked to provide their notes and these were photocopied before being returned. The numbers of records obtained were 18, 16 and 18 respectively.

Correspondence Between Lecture Signals and Students' Records

For each lecture, a copy of the blackboard signals was compared with the notes of each student. On the copy of the board signals, those signals recorded by the student were indicated with a coloured marker pen. Signals not recorded by the student were then easily identified. Those portions of the student's notes that corresponded with board signals were also marked, and the remaining, unmarked portions were then traced to other types of lecturer signals (such as verbal comments or slides).

The blackboard signals were numbered and a grid used to check those which each student recorded. Using the completed grid, it was possible to determine (i) the number of signals recorded by each student, and (ii) how many students in the sample recorded each signal.

Comparison of blackboard signals with student notes also allowed identification of inaccurate notes.

A similar procedure was used for both verbal signals (comparing a transcript with each student's notes) and signals presented on slides (using a copy of the content of slides shown).

Correspondence Between Information Units and Students' Notes

As for blackboard signals, the information units inferred from the lecture signals were numbered and a grid used to check those information units for which each student had made relevant notes.

RESULTS AND DISCUSSION

Number of Information Units Developed

Some contextual information arising from the analysis of the lectures was the number of information units inferred from the signals used. (See Table 1).

TABLE 1

Number of information Units

Lecturer	Number
A	188
B	139
C	257

The number of pieces of information which students needed to process to make sense of the lecture was surprisingly high. In the case of lecturer C, these ideas were delivered at an average rate of one every 11 seconds. Lecturer C has a rapid delivery style, but even the more typical lecturers A and B developed separate ideas every 16 and 22 seconds, respectively.

Correspondence Between Lecture Signals and Students' Notes

The percentages of board signals recorded by students in two of the lectures in this study are shown in Table 2.

TABLE 2

Percentage of blackboard signals recorded

% b/b signals recorded	% students Lecture B	% students Lecture D
≥ 95	25	6
≥ 90	55	50
≥ 80	55	83
≥ 70	75	89
≥ 60	100	94
≥ 55	100	100

Contrary to the beliefs of many lecturers, not all students record all that is written on the blackboard (although all students did record at least half of the blackboard signals). This should not in itself be taken to indicate poor efficiency of the lecture medium because some evidence will be presented later to suggest that students are selective in what they record.

The number or student records originating from verbal signals other than those that re-stated blackboard signals was negligible. At least for lecturers B and D in this study, it seems that if the lecturer considers it important for students to record some information, then it is insufficient to discuss this knowledge without the support of blackboard signals.

Least Frequently Recorded Blackboard Signals

The blackboard signals recorded by the least number of students were identified and, as a result of consideration of common factors, classified into the following categories:

1. Late insertions. Examples included corrections and the insertion of a chemical equation into an earlier stage of a calculation. Failure to record late insertions occurred even when the lecturer emphasised that an insertion was being made. It remains uncertain whether this is due to preoccupation by the students in catching up with their note-taking.
2. Subscripts/superscripts. The superscript in E° and the subscript in ΔH_f were frequently omitted by students. It is possible that the significance of these was not appreciated by the students.
3. Asides/digressions. When the lecturer deviated from the main point of the lecture, usually with fading voice emphasis, blackboard signals were commonly not recorded.
4. Obvious. When elementary steps were included in a calculation, these were often omitted from students' records.
5. Redundant. If the formulas of three compounds were listed as exemplars of a phenomenon, one was frequently ignored.
6. Irrelevant. Two texts were recommended as suitable alternatives for this course. When page references were given for both texts, many students recorded only one of them. Presumably this one referred to the text which they had bought.

It is significant that omissions of types 3,4,5 and 6 seem to be the result of conscious decisions by the students.

Inaccuracies

The number of inaccurate recordings made by each student was small - an average of 3.4 per student in lecture A, 1.5 in lecture B, and 2.0 in lecture D.

The most common types of inaccurate recording are listed here:

- Inaccurate translation of numbers (e.g.. 0.189 instead of 0.186).
- Inaccurate chemical formulas and equations (e.g., AlO_3
- Inaccurate mathematical symbols and units (e.g., + instead of -, kj instead of kJ, $\Delta T = K_f = m$ instead of $\Delta T = K_f \times m$).
- Incorrect nomenclature (e.g., iso butyl instead of isobutyl).
- Incorrect structural formula (e.g., =CH4= instead of =C=).
- Confusion of conventions (e.g., "work done on" instead of "work done by").
- Significance not appreciated. The omission of subscripts and superscripts, referred to earlier, is probably of this type. For example, during a discussion of delocalisation of bonding in benzene, a diagram of the carbon skeleton was drawn with arrows representing electron spin pointing alternately up and down in the p orbitals on adjacent carbon atoms. Some students ignored these arrows, some drew all arrows pointing upwards and some drew an arrow in each lobe of each p orbital.

Correspondence Between Information Units and Students' Notes

Of the 188 inferred information units in lecture A, 63 were supported by blackboard signals and only verbal signals were used for the remaining 125 information units. If students record a negligible number of verbal signals, then even the best note-takers (those who record all board signals) would at best have made records relevant to only 33% of the information units identified in this lecture. These numbers cannot be taken as typical from lecture to lecture. Of the 139 information units in lecture B, 92 (67%) were developed with the use of board signals and 47 (33%) were conveyed by verbal signals only.

Lecturer C was shown a list of the 257 information units inferred from the signals used during his lecture and asked to identify the 50 information units that he considered most crucial for the purposes of the lecture and for which he would expect that the students would have made some records. He identified 84 information units and Table 3 shows the numbers of students whose notes referred to these information units.

TABLE 3

Frequency of records related to the 84 information units identified as being the most important in Lecture C.

(Size of student sample = 16)

Information units		students
28	recorded by	0
9		1
4		2
9		3
4		4
3		5
4		6
7	recorded by	7
3		8
1		9
3		10
2		11
2		12
5		15

For 68 of the 84 information units considered to be the most important, related records were made by less than half of the students (i.e., by 7 or less of the 16-student sample). Obviously the quantity of student records in this lecture did not measure up to the expectations of the lecturer.

Correspondence Between Slide Signals and Students' Notes

The extent of student notes taken from slides during lecture C was extremely variable from student to student, and from slide to slide. Relevant factors include (i) the extent of verbal commentary used in association with each slide and (ii) the time for which each slide was displayed (in relation to the time necessary to copy the relevant information).

CONCLUSION

In this work a method has been developed to evaluate the quantity and quality of students' notes during lectures in any particular context. Because of enormous differences in context from lecture to lecture (including lecturing style and the nature of the subject matter) it does not seem sensible to pursue quantitative estimates which might be claimed to be generalisable to all lectures and all lecturers. However further work along the lines described here may well allow some generalisable conclusions concerning factors that influence the quantity and quality of students' notes, the sense that students can make of their notes in the short and long term, and the potential usefulness of notes for future learning.

REFERENCES

HARTLEY, J., & CAMERON, A. (1967). Some observations on the efficiency of lecturing. Educational Review, 20, 30-37.

HARTLEY, J., & DAVIES, I.K. (1978). Note-taking: a critical review. Programmmed Learning and Educational Technology, 15 207-24.

HARTLEY, J., & MARSHALL, S. (1974). On notes and notetaking. Universities Quarterly, 28, 225-35.

HOWE, M.J.A. (1975). Taking notes and human learning. Bulletin of the British Psychological Society, 28, 158-62.

HOWE, M.J.A., & SINGER, L. (1975). Presentation variables and student activities in meaningful learning. British Journal of Educational Psychology 45, 52-61.

MADDOX H., & HOOLE, E. (1975). Performance decrement in the lecture. Educational Review, 28, 17-30.

STANTON, H.E. (1976). The use of slides and the blackboard to illustrate lecture material. The Australian University 14, 43-7.

WEST, L.H.T., FENSHAM, P.J., & GARRARD, J.E. (1985). Describing the cognitive structures of learners following instruction in chemistry, in Cognitive Structure and Conceptual Change, West, L.H.T. & Pines, A.L. (eds.). Academic Press, 29-49.

Research in Science Education 1989, 19, 47 - 56.

SCIENCE EDUCATION IN THE LONG SHADOW OF MICHAEL POLANYI

Roger T. Cross and Ronald F. Price

INTRODUCTION

In this article we continue our exploration of historical factors that may have played, and may still play a part in the formulation of school science experiences. Our selection of Polanyi is made on the grounds that he was the chief architect of the "The Freedom in Science Movement". It is our belief that his persistent advocacy for freedom, and opposition to the emerging "Social Responsibility of Science Movement" (hereafter referred to as the "Movement") may have had a profound impact on the structure of post war science. Although seemingly remote from Australia the influence of the "Movement" extended to Australian Science. The small scientific community here was largely composed of "Oxbridge" graduates and a "significant number had come under the direct influence of Bernal himself" (Johnston, 1988).

The links between Polanyi and science teaching in Australia appear on the surface extremely tenuous. However, it should be remembered that the aims and objectives of the "Australian Association of Scientific Workers", formed in remarkable fashion in 1939 by Eric Ashby and others when 110 men and women attended the inaugural meeting at the University of Sydney on the 19th July were precisely those that Polanyi opposed. The aims of the Association included the development of a science for Australia and promoting science for the welfare of people through planning (The Australian Journal of Science, 1939). Other concerns were the development of science teaching in Australia (R.E.B.M., 1939) and the status of women in science (A.A.S.W., 1942). This Association mirrored the "Mother Association" in the UK, an association which Bernal transformed during the 1930s, so much so, that it posed a "direct challenge to the traditional attitude fostered by the elders of science" (Goldsmith, 1980, p.79).

We will show that Polanyi went to extraordinary lengths to oppose the "Movement". He linked the "Movement" firmly with Soviet style planning, Marxism and the horrors of dialectical materialism. Writing of dialectical materialism, he claimed that it "conjures away the contradiction between the high moral dynamism of our age and our stern critical passion which demands that we see human affairs objectively ie, as a mechanistic process in the Laplacean manner" (Polanyi, 1958, p.228).

BIOGRAPHICAL DETAILS

Polanyi was born in Budapest in 1891 and educated both in Budapest and Karlsruhe in Germany. In 1923 he become "Privatdozent" at Technische Hochschule, Berlin and member of the prestigious Kaiser Wilhelm Institute for Physical Chemistry. Later he resigned over the anti-Jewish legislation and made his way to England where, in 1933, he became Professor of Physical Chemistry at the University of Manchester and later, in 1948, the first Professor of Social Studies at that University. In 1944 he was elected to the Royal Society (Chambers Encyclopaedia, 1967).

Polanyi's academic career can be divided into two distinct periods, firstly, his work as a physical chemist, the majority of his publications coming before 1936 (information taken from his son John's analysis of his publications, Note 1); and secondly, his work as a philosopher where he was mainly concerned with the process of scientific discovery (Kane, 1984, p.3).

See note 2 for a list of Polanyi's major publications. Overlapping both periods was his campaign of defence of freedom in science. It is indeed interesting to speculate whether this, seemingly all-consuming interest, did not actually lead him into his second career.

POLANYI VERSUS BERNAL

We have paid tribute to Desmond Bernal as a leader of the "Movement" and in particular to Bernal's Social Function of Science (1939). In this book, he appealed to science teachers to change science education, and to adopt a leadership role in the community when scientific issues arose (Cross and Price, 1988). Bernal's proposals for the restructuring of science assumed that science was a value-laden activity (Bernal, 1938). He pleaded for a restructuring of science so that it could be planned to take account of the failure of science, as it was practised, to provide a reasonable standard of living for all people. It is within this background of challenge to established science that we must see the activities of Michael Polanyi.

Polanyi's writings, almost from the time he left Germany in 1933, demonstrate his ideological position. In the preface to The Contempt of Freedom (1940):

> Attempts to protect liberty against collectivism were met with scorn by the intellectual advance guard of the time. Progress had become antagonistic to liberty, disregarding its claims, and bitterly exposing its limitations to contempt and ridicule.
>
> Only now that the peril of freedom has become deadly has its value again been recognised ..... (p.v)

His opposition to the "new radical utilitarian valuation of science" (Goldsmith, op.cit. p.85) was total. In The Logic of Liberty (1951) he states his fears:

> In this *milieu*, science as a pure search for truth can hardly be expected to regain the respect which it previously enjoyed. While such forces prevail, society is unlikely to regard itself as dedicated to the continued cultivation of an intellectual heritage ..... on the contrary, the tendency will remain for the State to claim ultimate responsibility for every activity ... including the progress of science. (op.cit., p.85)

He berated Hogben for the politicisation of science in his famous Science for the Citizen (1938). In the epilogue Hogben discusses a new social contract by the radical scientists (pp. 1077-1090). The enormous circulation of this book possibly provided more in the way of science and technology education for citizens than did schooling! He claimed that Hogben, in league with Bernal, attempted to show that scientific discoveries can be made to order (Polanyi, 1939, p.186). In 1941 Polanyi, among others formed The Society for Freedom in Science (Werskey, 1972, p.244), hereafter referred to as the "Society". John Baker was intimately connected with the group and wrote bitter attacks on the radical scientists (Baker, 1939, Baker and Tansley, 1946). In his obscure book The Scientific Life (Baker, 1942, p.49) Baker lists some of the aims of the Society. Foremost among these being the preservation of academic freedom, a proposition that was central to Polanyi's attacks on the "Movement". In The Foundations of Academic Freedom Polanyi (1947) states:

> Academic freedom can claim to be an efficient form of organization for discovery in all fields of systematic study controlled by a tradition of intellectual discipline. (p.11)

> Th(e) unity between personal creative passion and willingness to submit to tradition and discipline is a necessary consequence of the spiritual reality of science. (p.11)

The fear that the members of the society had about the influence of Marxism, and the Radicals' praise for the arrangements for science in the USSR are graphically portrayed in many of the publications and public discussions at this time, and these appeared to intensify as the cold war took its toll on liberal thought in the West (Polanyi, 1956).

During the early years of the "Society", communication in the journal Nature was blocked by the editor, Sir Richard Gregory, who was a member of the "Movement". Also frustrating was the establishment in 1938 of the Division of the "British Association for the Advancement of Science" called "The Social and International Relations of Science" under the auspices of the Cambridge group.

By 1946 however, the tide was turning and Nature published an attack on the "Movement" by Baker and Tansley (op.cit.). Werskey claims that Polanyi and others in the "society" skilfully exploited the more radical of the "Movement's" admiration for Soviet Communism after the war (op.cit., p.245). They were able to use the fear generated by "Cold War" politics to isolate the radicals from the less politically extreme faction (the reformists). Polanyi also appears to have linked the concept of freedom of science with belief (Polanyi, 1946 and 1948), which may have helped his cause, especially when it came to references to the clearly ungodly Stalin.

In 1953 the reactionary European organization called the "Congress for Cultural Freedom" convened a Conference called the "Hamburg Congress on Science and Freedom" of which Polanyi was Chairman of the Organising Committee. The aim of the Conference was to consolidate the reconquest of freedom. This was to be achieved by the promotion of intellectual freedom in communist countries, by the organization of science in free countries and by the clarification of the philosophical foundations of the concept of freedom in science (Congress for Cultural Freedom, 1955, p.10).

Furthermore, in July of the following year (1954), under the auspices of the "Congress for Cultural Freedom", the "Committee on Science and Freedom" was formed, the Chairman being Michael Polanyi (See Note 3). We do not suggest that the impact of the conservatives was the only reason for the dissipation of the "Movement". However, it was a factor and we contend that the conservatives had a nullifying influence on the "Movement" within science itself.

POLANYI'S CONCEPT OF FREEDOM AND SCIENCE

Polanyi's preoccupation with freedom is perhaps explained by the situation in Nazi Germany of the 1930s, a situation which became intolerable as early as 1933. In his publication "The Foundations of Academic Freedom" (1947) he rationalizes his concern by writing:

> "(t)he analysis of the grounds on which freedom rests is of great practical interest to those who love freedom. For by clarifying these grounds we may hope to make them more secure. By raising some of the great questions concerning the nature and justification of freedom we may try to eliminate some of the ambiguities of freedom which have particularly in our days, laid freedom open to misunderstanding, and worse, to perversion and discredit"(p.3).

Polanyi believed there were two extremes to freedom, nihilism and totalitarianism. The complete freedom of the individual, free from any personal constraint on the one hand and the freedom which can be considered a 'liberation from personal ends by submission to impersonal obligations' (p.3). The latter condition can, according to Polanyi, easily become a total self-surrender to the state. In order to resolve the dilemma between these two opposing states, where "self-surrender does not seem to accord with our sympathy for the individual pursuing his own happiness" (p.4) and individual selfishness, he uses the example of academic freedom.

The foundation of academic freedom is the liberty to choose whatever problem one wishes to study, free from all external controls, the only sanctions being the moral ones that apply by virtue of scientists belonging to a community. Polanyi attempts to use the concept of academic freedom to knit together his two concepts of freedom while striking what he hopes will be a mortal blow against the planning of science as advocated by the "Movement". He set the scene by quoting Enrico Fermi:

> Experience has indicated that the somewhat haphazard exploration of the field of knowledge that results from an intensive freedom of the individual scientific worker to choose his own subject is the only way to ensure that no important line of attack is neglected. (p.5)

Accordingly, "freedom is an efficient form of organization" (p.5) because it allows for the essential spontaneity for the progress of science. He claimed that the professional traditions of science are a strong check on any possible excesses. The strength of this tradition according to Polanyi "rivals the Church of Rome" in "continuity of doctrine and strength of corporate spirit" (p.11). There is in this system no disharmony; the unity between creative passions and the willingness to submit to discipline is a "necessary consequence of the spiritual reality of science" (p.11). These, for Polanyi, are the essential attributes of freedom.

THE LONG SHADOW

The period of intense activity of the "Movement" evaporated soon after 1946 although UNESCO and the Pugwash Conferences (in both of these Bernal was an important figure) are reminders of their influence. Not until the mid 1960s do we again see the emergence of a change in the social climate for science with the popular writings of environmentalists such as Rachel Carson.

The days when Bernal was able to influence science teachers were soon coming to an end (Bernal, 1946). Elsewhere we have discussed his blueprint for a science education, which would take into account the changed nature of science and prepare citizens to evaluate the issues surrounding the introduction of technology and even the directions in which science should progress (Cross and Price, 1988). Polanyi on the other hand appears to have had a very different view of the purpose of science education:

> The premises of science are taught today roughly in three stages. School science imparts a facility in using scientific terms to indicate the established doctrine, the dead letter of science. (1946, p.29)

During the post-war period in Australia there was a rapid increase in secondary education and with it, science teaching. The transfer of the explicit and implicit culture of science ensured that the values inherent in science were transferred from one generation of students to the next generation of science teachers and so on. Science courses have continued to reflect the reductionist nature of science and the myth of the search for truth uninfluenced by social factors. Maxwell (1984) has called this the Philosophy of Knowledge. It has been a unifying feature of the changes in the science curriculum since the end of the World War II. At no stage do we find that the structural features of science are examined and even less questioned.

The question to ask is, could it have been different? We can, of course, only speculate answers. It is tempting to suggest that if the "Movement" had continued to flourish, science would be very different and perhaps it would have moved closer to what Maxwell has called the Philosophy of Wisdom (op.cit.), which asserts that the "basic task of rational inquiry is to help us develop wiser ways of living, wiser institutions, customs and social relations, a wiser world" (p.66). He claims that if put into place it would radically change education:

> (m)any current conflicts, difficulties, failings, would disappear. All education would be what children instinctively want it to be: learning how to live, learning about how to realize what is of most value to us in the circumstances of our lives. (p.78)

None of the STS courses examined, questions the role of science, its reductive characteristics and the framework of the profession which encourages publication rather than excellence and the nature and type of discovery through funding and the "Gatekeepers" controls. The result of the acceptance of the ways in which science and technology have restructured, and are restructuring society almost without debate, can be seen in many of the latest curriculum materials which describe themselves as courses that examine science in relation to society. In fact they simply demonstrate the impact of science on society rather than encourage evaluation.

CONCLUSION

Science teaching in Australia has been dogged by a lack of independence from the top-down pressures of the tertiary institutions and overseas, particularly British, influences. In a future paper we will examine the influence of Professor Harry Messel of Sydney University and his Philosophy of Science as exemplified by the Wyndham Science Course for secondary schools in NSW.

Science teaching continues to ignore such questions as, whose interests are served by the managers of scientific research? There is an absence of discussion about autonomous technology and growth economics advocated by

Australian and other governments. Even the curious juxtaposition of caution and demand for more technology by Barry Jones in Sleepers, Wake! (1982) has failed to stimulate discussion.

In this article, we have attempted to indicate the possible influence of Michael Polanyi, an ignored but powerful figure, in determining the direction of science into the 1960s and beyond. We have indicated that science teaching in Australia, as elsewhere, has continued to slavishly follow the influences of the scientific establishment. Australia has failed to create its own identity in these areas and even today could lose the opportunity that curriculum reform presents to break the shackles of the past. There is an urgent need to draw attention to the underlying historical factors influencing the philosophy of science as espoused by science education today.

REFERENCE NOTES

Note 1, According to his son, Polanyi published 218 scientific papers. Interestingly for this study, there was a significant drop off in output from the end of 1936 (Essays Presented to Michael Polanyi, 1961).

Note 2, M. Polanyi's Major Works:-

: 1933. Atomic Reactions, London, Williams and Norgate.
: 1935. USSR Economics, Manchester, Manchester University Press.
: 1940. The Contempt of Freedom, London, Watts.
: 1945. Full Employment and Free Trade, Cambridge, Cambridge University Press.
: 1946. Science, Faith and Society, Riddell Memorial Lecture, University of Durham.
: 1951. The Logic of Liberty, London, Routledge and Kegan Paul.
: 1958. Personal Knowledge, London, Routledge and Kegan Paul.
: 1959. The Study of Man, London, Routledge and Kegan.
: 1960. Beyond Nihilism, London, Cambridge University Press.

Note 3, M. Polanyi, this information was obtained from the inside cover of a pamphlet published by "The Committee on Science and Freedom" entitled The Magic of Marxism and The Next Stage of History, 1956.

REFERENCES

A.A.S.W. (Report of the Australian Association of Scientific Workers). (1942). The Status of Women Graduates Employed in Science in New South Wales. The Australian Journal of Science, 4, 121-125.

BAKER, J.R. (1942). The Scientific Life. London, George Allen and Unwin.

BAKER, J.R. (1939). Counterblast To Bernalism. New Statesman. 29th July.

BAKER, J.R. & TANSLEY, A.G. (1946). The Course of the Controversy on Freedom in Science. Nature, 158, 4017, 574-6.

BERNAL, J.D. (1946). Teaching in General Education. School Science Review, 27, 102, 150-158.

BERNAL, J.D. (1939). The Social Function of Science. London, George Routeledge.

BERNAL, J.D. (1938). The Social Relation of Science. Supplement to Nature, 141, 3573, 723-745.

CHAMBERS' ENCYCLOPAEDIA. (1967). Polanyi, M. Chambers' Encyclopaedia. Pergamon.

CONGRESS FOR CULTURAL FREEDOM. (1955). Science and Freedom. London, Martin Secker and Warburg.

CROSS, R.T. & PRICE, R.F. (1988). J.D. Bernal and Science Education: A tribute to the 50th anniversary of the publication of "The Social Function of Science", Research in Science Education, 18, 152-159.

ESSAYS PRESENTED TO MICHAEL POLANYI. (1961). The Logic of Personal Knowledge. London, Routledge and Kegan Paul.

GOLDSMITH, M. (1980). Sage. A life of J.D. Bernal. London, Hutchinson.

HOGBEN, L. (1938). Science for the Citizen: A Self Educator Based on the Social Background of Scientific Discovery. London, George Allen and Unwin.

JOHNSTON, R. (1988). Social Responsibility of Science: The Social Mirror of Science, in R., Macleod (ed.). The Community of Science. Melbourne, Oxford University Press.

JONES, B. (1982). Sleepers, Wake! Technology & the Future of Work. Melbourne, Oxford University Press.

KANE, J. (1984). Beyond Empiricism: Michael Polanyi Reconsidered. New York, Peter Lang.

MAXWELL, N. (1984). From Knowledge to Wisdom: A Revolution in the Aims and Methods of Science. New York, Basil Blackwell.

POLANYI, M. (1939). Rights and Duties of Science. The Manchester School of Economics and Social Studies, October, 175-193.

POLANYI, M. (1946). Science, Faith and Society. Riddell Memorial Lecture, University of Durham, London, Oxford University Press.

POLANYI, M. (1948). Can Science Bring Peace? in The Challenge of Our Time. London, Percival Marshall.

POLANYI, M. (1947). The Foundations of Academic Freedom, Occasional Pamphlet No. 6, Society For Freedom in Science.

POLANYI, M. (1951). The Logic of Liberty. London, Routledge and Kegan Paul.

POLANYI, M. (1940). The Contempt of Freedom. London, Watts and Co.

POLANYI, M. (1956). The Magic of Marxism and the Next Stage of History. A Special Supplement to the Bulletin of The Committee on Science & Freedom, Congress for Cultural Freedom.

POLANYI, M. (1958). Personal Knowledge. Chicago, The University of Chicago Press.

R.E.B.M. (1939). Australian Association of Scientific Workers: The nature of science, teaching in schools, The Australian Journal of Science. 2, 90-92.

THE AUSTRALIAN JOURNAL OF SCIENCE. (1939). Science and Society. The Australian Journal of Science, 2, 15-16.

WERSKEY, P.G. (1972). British Scientists and 'Outsider' Politics 1931-1945. In B. Barnes (ed.), Sociology of Science, Harmondsworth, Penguin.

Research in Science Education 1989, 19, 57 - 66.

ASSESSING UNDERSTANDING: A PHENOMENOGRAPHIC APPROACH

Gloria Dall'Alba, Eleanor Walsh, John Bowden, Elaine Martin,
Ference Marton, Geofferey Masters, Paul Ramsden, and Andrew Stephanou

INTRODUCTION

Current methods of assessment in science frequently focus on the reproduction of facts, formulae and procedures, often at the expense of assessing understanding of the underlying concepts and principles. There is a large body of evidence that many students are able to pass examinations in science subjects and yet have limited or inaccurate understandings of key concepts and principles in these subjects (for example, Johansson, Marton, & Svensson, 1985). Furthermore, there is evidence that the assessment affects student learning (Entwistle & Ramsden, 1983; Newble & Jaeger, 1983).

This paper describes a research study that is concerned with the assessment of students' levels of understanding of key concepts and principles in science. In the first phase of the study, students' understandings of fundamental concepts and principles in kinematics are examined. Levels of understanding are identified for each concept or principle using a phenomenographic approach. These levels of understanding will be used in the development of new methods of assessment that reward and encourage understanding.

THE PHENOMENOGRAPHIC APPROACH

What is phenomenography?

Phenomenography is a research approach for describing the "qualitatively different ways in which people experience, conceptualise, perceive, and understand various aspects of, and phenomena in, the world around them". This implies that phenomenography is not concerned only with the phenomena being investigated, nor the people who are experiencing the phenomena. Rather, it is concerned with the relation between the two, that is, the ways in which people experience or think about the phenomena (Marton, 1986, p.31). Accordingly, the descriptions that arise from a phenomenographic study can be described as relational and experiential. More specifically, the present study is concerned with the ways in which physics students experience or understand selected concepts and principles relating to kinematics.

Phenomenographic descriptions are based on ways of understanding particular phenomena or aspects of phenomena and, so, are qualitative. This does not imply that quantitative content cannot be explored phenomenographically but, rather, the descriptions would deal with the qualitatively different ways in which the quantitative content is understood.

The content that is being thought about or experienced (such as principles relating to kinematics) is seen as an integral part of the way in which it is understood; descriptions are presented in terms of the content. Thus, phenomenography can be referred to as content-oriented. In summary, "phenomenography provides descriptions that are relational, experiential, content-oriented, and qualitative" (Marton, 1986, p.33).

Categories of description

In phenomenographic studies it has been found repeatedly that "each phenomenon, concept, or principle can be understood in a limited number of qualitatively different ways" (Marton, 1986, p.30). The present study assumes that a limited number of conceptions of the concepts and principles under study can be found.

In phenomenographic research the description of the conceptions constitutes the main outcome. The conceptions are presented in categories of description. These categories are drawn from the data; there is no attempt to "fit" the data into pre-determined categories. The categories are based on the most distinctive features that differentiate one conception from another. The categories are presented in the form of a hierarchy of conceptions, reflecting increasing levels of understanding and displaying the relation between the conceptions. (The focus on making explicit the relations between the conceptions is one of the characteristics of phenomenography that distinguishes it from other approaches, such as alternative conceptions research.) It is not claimed that the categories represent a developmental sequence; the way in which the development of conceptions occurs is an empirical question.

THE RESEARCH STUDY

Research design

Thirty first-year students in two tertiary institutions and sixty year 12 students in six schools were interviewed about their understanding of particular concepts and principles being investigated (including acceleration, relative speed, Newton's Laws, composition of velocities, and terminal velocity). These students of physics responded to a total of 14 questions, with each student answering four to five questions in an interview of approximately one hour. Hence, 25 to 30 responses to each question were obtained.

Exemplary question

The responses to a question about relative speed will be used to illustrate the results of a phenomenographic analysis, and to discuss the usefulness of these results in assessing understanding. (The results of the phenomenographic analysis that follow may be contrasted with the Hoz and Gorodetsky (1983) study in which students responded in written form to two relative speed questions. The responses were analysed in terms of the solution strategies. In the present study the analysis is concerned with students' understanding of relative speed, with the solution strategy forming only part of the data.)

In the present study the students were interviewed about a question that was presented in written form, as follows:

> Martha and Arthur are running along a straight, level road at constant speed. Arthur is ahead of Martha. Arthur's speed is less than Martha's speed.
>
> How far must Martha run before she catches up to Arthur and how long will this take her?

The situation may be depicted as shown in Figure 1. (Figure 1 was not part of the question presented to students.)

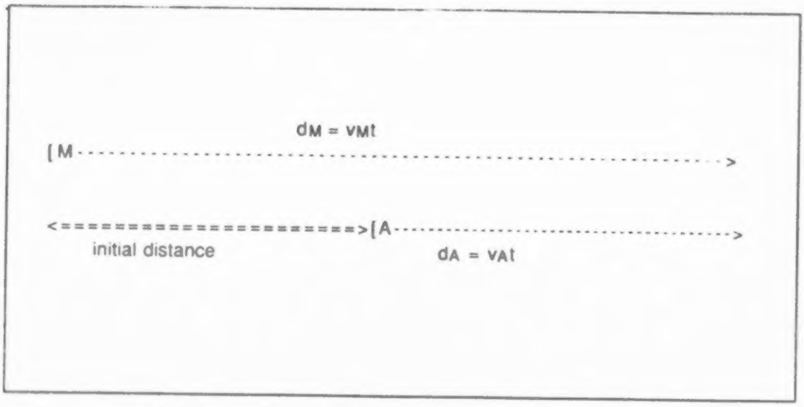


Figure 1. Illustrating the question: Arthur and Martha

Summary of categories of description: Arthur and Martha

In this paper the categories of description are presented in summary form, focusing on the students' conceptions of relative speed. The students' procedures for solving the problem (which support the categories) are not included here but can be found, along with a more complete description of the categories, in Walsh et al. (1989). The summary that follows includes the key features of the conceptions of relative speed and an extract from the interview transcripts to illustrate each conception.

The scalar terms, "speed" and "distance", rather than "velocity" and "displacement", are used in the description of the categories. Students used the vector and scalar terms interchangeably. As this distinction is not the main focus of the question and does not affect the method of obtaining the solution to the problem, the scalar terms are considered to be more accessible.

Category Rs Relative speed as a new entity; initial distance as a fixed quantity The individuals are united in a system in which a new entity, relative speed, is formed. Relative speed or "catching speed" is the rate at which the initial distance between them (or the initial gap) diminishes to zero. (Numbers in parentheses following the quotes refer to transcript numbers.)

> This fellow Arthur is ahead of Martha by some distance and he's travelling slower than her by some amount so the speed with which she closes the gap is equal to the difference of their speeds. (90)

Category Rd Relative distance as variable quantity, function of time.

The individuals are again combined as a system, but in this category the distance between them (the relative distance) is expressed as a function of time. The solution to the problem is given as a special case when this distance diminishes to zero. Relative speed is imported via the mathematics into the expression for the relative distance but it is not the focus, although it is acknowledged as the appropriate way to express speed in obtaining a solution to this problem. In this category (of which there is only one example) the solution to the problem is constructed from the equations of motion (the general statement), taking into account the boundary condition of an initial distance between the runners. Thus the problem can begin at any point along the path, where t now represents instantaneous time, not a time interval.

Use is made of the kinematic equations, $x_A(t) = v_A t$ and $x_M(t) = v_M t$, where $x_A(t)$ and $x_M(t)$ are the total distances travelled by Arthur and Martha, respectively, up to time t. Forming the instantaneous distance between the runners, $x_A(t) - x_M(t)$, the initial distance must be taken into account, as time is measured from the instant at which the initial gap is established, and so:

$$\underset{\text{instantaneous distance}}{x_A(t) - x_M(t)} = \underset{\text{initial distance}}{[x_A(0) - x_M(0)]} + (v_A - v_M)t$$

Thus, at any given instant, t, the size of the instantaneous gap between the runners can be calculated. The answer to the question posed is obtained by allowing the instantaneous distance to diminish to zero (with t now representing the total time interval):

$$0 = [x_A(0) - x_M(0)] + (v_A - v_M)t$$

Category Di Distance M = Distance A + initial distance MA

Martha runs the same total distance as Arthur plus the initial distance between them. In addition, it is recognized that Martha and Arthur are each running for the same length of time. Thus, a solution to the problem is possible. The primary focus is on individuals each running a separate total distance, with the individual distances related through the initial distance.

> The distance travelled by Martha in that time equals the distance travelled by Arthur + x. (7)

That is, the distance can be given in two ways:

$d_M = d_A$ + initial distance and $d_Mt = v_Mt$, $d_At = v_At$

thus $v_Mt = v_At$ + initial distance

The solution in category Di is the same as in categories Rs and Rd, although in category Di relative distance and relative speed are not explicitly recognised.

Category D Distance M : Distance A

The focus is on the total individual distances travelled by Martha and Arthur, without considering the relation between the two. As in category Di, it is recognized that each runs for the same length of time, allowing expressions for time to be equated.

> t's constant so you put t equals d on v for both of them so d on v equals d on v, velocity for her and velocity for him ... you just find the ratio of their velocities and then that'll be the distance he runs in comparison to the distance that she runs and it takes the time for her to catch up with him. (64)

Recognizing that time is the same for each individual,

$v_M = d_M/t$ and $v_A = d_A/t$.

The student obtains a ratio of velocities equal to a ratio of distances:

$$t = \frac{v_M}{v_A} = \frac{d_M}{d_A}$$

The relationship between individual distances via the initial distance is not recognized, that is, distance is not seen in two different forms - as a measurable quantity and as related to velocity and time. Hence, there is no alternative way of calculating distance d_M or d_A and the problem cannot be solved.

Category Ut Discontinuous Perspective - Unitizing Time

The focus is on how far Martha and Arthur individually run in a discrete unit of time. Numerical examples are used to show that the initial distance diminishes after each time unit, a stepwise calculation. Depending on the numerical values chosen, it can be shown that if at one step in the calculation Martha is behind Arthur and after the next unit of time she is in front of Arthur, the solution is arrived at by iterating, that is, splitting the time unit and checking again to find where Martha is in relation to Arthur. In this way a solution may be obtained for a particular numerical example, but not necessarily an exact solution, nor a general (algebraic) solution.

> I would work out like how much the distance has decreased.... You keep working it out until you come to a point where ... like Martha was just behind and then say a second later she would be just in front, so you know it is going to be between it.... If it was between five and six seconds I would use 5.5 seconds as the time and work it out that way. (30)

Category Ud Discontinuous Perspective - Unitizing Distance (Zeno's Paradox)

The initial distance between Arthur and Martha is acknowledged; the focus is on the distance run separately by each runner in the same time interval. The time for Martha to run this initial distance is calculated using arbitrary numerical values for her velocity and for the initial distance. The distance that Arthur has run ahead during the same period is then calculated (using an arbitrary numerical value for his velocity). Arthur is, therefore, always ahead of Martha by some diminishing amount and Martha never catches up. Thus, the problem is insoluble.

> The difference between Arthur and Martha will be D2, that is, the distance Arthur covered while Martha was covering distance D1.... I know the time required to cover that distance so I can work it out. While Martha is covering the second distance Arthur himself keeps running and covers another distance D3. (52)

Ordering principles

The categories of description have been ordered in terms of the level of understanding of relative speed that is displayed. Categories Rs and Rd are considered to describe the highest level identified, with the level of understanding decreasing through Di, D, Ut and Ud. The ordering principles are described below.

In all of the categories, speed, distance, and time are treated as significant elements, although their treatment varies. The identification of conceptions and ordering of the categories is based on the way in which these elements are treated, in particular, on what constitutes the focus of the conceptions.

Categories Rs and Rd each consider the gap (the initial distance between Arthur and Martha) as an entity, combining the individuals into a system. In Rd the primary focus is on the instantaneous magnitude of this gap, while in Rs the initial gap is subsidiary to the relative speed. The key feature in Rs is an intuitive focus on the speed of the system, by treating the motion of Martha as relative to Arthur's motion. In Rd this same notion of relative speed is imported through the mathematical derivation from the kinematic equation. An expression is chosen that describes the instantaneous gap and from which the particular solution emerges as the gap closes. In Rd relative speed is acknowledged but it is not the focus.

Categories Di and D focus on the total individual distances travelled from the initial positions in the same time interval. In D only the individual path lengths are examined and, therefore, a solution is not reached. In contrast, in Di the individual paths are linked through the initial distance between the runners, leading to a solution. In Ut and Ud there is a focus, in a step-wise fashion, on the total distance covered by each individual but the two distances are not linked through the initial separation. In Ut time is unitized and in Ud distance is unitized.

In categories Rs and Rd the initial distance is seen as a relative distance. In Di, D, Ut and Ud the initial separation is not focused upon as the initial distance between individuals. However, in Di the initial distance is inferred in order to link the total distances of the individuals. Rd, Rs and Di lead to algebraic solutions of decreasing generality and elegance. In D an attempt is made at an algebraic solution that is only partially successful. Ut leads to an approximate numerical solution. Ud does not lead to a solution at all.

ASSESSING UNDERSTANDING

The next phase of the present research concerns the assessment of student learning. That phase will involve the design of some assessment items that allow a range of understandings to be expressed. (It is likely that these items will closely resemble the interview questions used in the study.) As the categories of description are ordered in terms of levels of understanding, students' responses to the assessment items can be graded with respect to the understanding displayed. In other words, the criteria on which students' responses are assessed and rewarded are specified in explicit terms in the categories of description.

In line with the notion of assessing understanding, the next phase of the study will seek to develop an interactive computer method based on the results of the phenomenographic analyses. Students will respond to questions presented on computer, with the generation of a "dialogue" between student and computer. Through this dialogue, each student's conception will be explored and classified (based on the earlier analyses of interviews).

Evidence of the link between assessment and student learning suggests that if assessment focuses on understanding so, too, will student learning. There are many advantages of adopting a phenomenographic approach to exploring understanding (see Bowden, 1986; Ramsden, 1988). By illustrating a range of understandings of particular content, invaluable information is provided to subject teachers about the conceptions that students bring to their classes or are likely to develop following instruction. The assessment can indicate the extent to which students have developed the desired conception and, in doing so, provide feedback on the teaching and learning that has occurred.

Adopting a phenomenographic approach to assessment discloses links between assessment and teaching. Such an approach affords, then, a basis upon which decisions relating to teaching can be made. The power of phenomenography in relation to teaching arises from two aspects of the categories of description. First, the categories are more than a map of the various responses to specific questions or phenomena. They represent attempts to explore what underlies such responses in a way that does not merely point to differences in understanding but, rather, illuminates the nature of those differences. Second, the categories of description make explicit the relation between the conceptions. This highlights for the teacher those aspects of a concept, principle, or phenomenon on which the students focus and those aspects that have been overlooked.

By presenting a clear indication of the existing and desired conceptions, phenomenography clarifies the objectives or desired outcomes of the teaching, framing them in terms of changes in students' understanding. The effectiveness of teaching will be enhanced, if teachers attend to what they are attempting to achieve.

In summary, phenomenography has much to offer teachers in promoting awareness of teaching and learning that focuses on student understanding, clarifying their objectives, highlighting the aspects of the content that are overlooked by the students, exemplifying the types of assessment items that reveal understanding, and providing criteria against which that understanding can be assessed.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the support of an Australian Research Council grant.

REFERENCES

BOWDEN, J.A. (1986). Student learning: Research into practice. University of Melbourne: Centre for the Study of Higher Education.

ENTWISTLE, N.J., & RAMSDEN, P. (1983). Understanding student learning. London: Croom Helm.

HOZ, R., & GORODETSKY, M. (1983). The effects of misconceptions of speed and time on the solution of speed problems. Proceedings of the International Seminar, Misconceptions in Science and Mathematics, Cornell University, Ithaca.

JOHANSSON, B., MARTON, F., & SVENSSON, L. (1985). An approach to describing learning as change between qualitatively different conceptions. In L.H.T. West & A.L. Pines (Eds.), Cognitive structure and conceptual change (pp.233-257). Orlando, Florida: Academic Press.

MARTON, F. (1986). Phenomenography - A research approach to investigating different understandings of reality. Journal of Thought, 21(3), 28-49.

NEWBLE, D.I., & JAEGER, K. (1983). The effect of assessments and examinations on the learning of medical students. Medical Education, 17, 165-171.

RAMSDEN, P. (Ed.) (1988). Improving learning: New perspectives. London: Kogan Page.

WALSH, E., DALL'ALBA, G., BOWDEN, J., MARTIN, E., MARTON, F., MASTERS, G., RAMSDEN, P., & STEPHANOU, A. (1989). Measuring understanding in physics: Relative speed. Physics Project Working Paper No.1. University of Melbourne: Centre for the Study of Higher Education.

Research in Science Education 1989, 19, 67 - 75.

TARGET STUDENTS IN YEAR 8 SCIENCE CLASSROOMS:
A COMPARISON WITH AND EXTENSION OF EXISTING RESEARCH

Barry C. Dart and John A. Clarke

INTRODUCTION

Research into student engagement patterns in school classrooms has hypothesized the existence of a group of students within a class who receives a disproportionate number of interactions. In whole-class interaction situations, this group has been variously called the "steering group" (Dahllof, 1971; Lundgren, 1972) or "target students" (Tobin, 1988; Tobin and Gallagher, 1987). "Steering group" and "target student" although similar in function are defined differently. The focus in this paper is on "target students" in science classrooms.

The term "target students" refers to those students in whole-class interactive environments who receive more interactions than others in the class. Two types of target students have been identified in these situations: Those selected by the teacher and those who involve themselves by raising their hands or calling out (Tobin and Gallagher; 1987). There appear to be between three and five or seven target students in most classes. Compared to other students in their science classes, they tend to be higher achievers, have higher levels of formal reasoning ability, a more internal locus of control and are more often male (Tobin, 1988; Tobin and Gallagher, 1987).

From interviewing teachers and observing classrooms, Tobin and Gallagher (1987) and Tobin (1988) have developed rationales for each type of target student. For the first type - those selected by the teacher - the researchers have deduced that these students are chosen to provide responses that will facilitate learning for all students. They allow the teacher not only to elaborate on the response but also to adjust the pace of the lesson. By providing correct answers, these students also contribute to the momentum and smooth flow of the lesson. The second type - those who initiate interactions with the teacher - arise, according to Tobin (1988) from questions directed to the whole class. This procedure favours risk-takers who raise their hands or call out a response. Those who raise their hands are more likely to be called upon by the teacher because teachers not only feel that such behaviour needs to be acknowledged or reinforced but also feel that such students are likely to know the correct answers.

Up to this point in target student research, the description of such students has focussed in the main on their personal characteristics such as sex, motivational orientation and levels of achievement and formal reasoning. In these descriptions, there has been no recognition of environmental factors. An extensive theoretical and empirical analysis of classroom communication (Clarke, 1987) has identified both personal and environmental characteristics that have the potential to contribute significantly to involvement in classroom interaction. Working within a Lewinian framework of B=f(P,E) (Lewin, 1951), the analysis identifies potentially significant "P" variables of conceptual level, locus of control, scholastic aptitude and formal reasoning ability and "E" variables of curriculum content, classroom dialogue and student perceptions of the psychosocial characteristics of the learning environment.

The major aim of this paper is to extend the field of target-student research by including environmental variables, in particular student perceptions of their science learning environment. In the process of doing this, comparisons are made with existing target student research findings in Year 8 science classrooms.

SAMPLE AND METHOD

Sample

The sample consists of three teachers and 108 Year 8 students in four classes studying "Water Solutions" (Stannard and Williamson, 1979) in a large metropolitan secondary school in Brisbane. Details of the student sample and a justification for it to be considered in many ways as typical of Year 8 students in Queensland is given elsewhere (Clarke, 1987, 1988). The distribution of teachers and students across classes is:

Class 1:	12 male 13 female students;	male teacher
Class 2:	15 male 13 female students;	male teacher
Class 3:	15 male 13 female students;	female teacher
Class 4:	15 male 12 female students;	female teacher
Total:	57 male, 51 female students	

Data Collection

(a) Classroom Dialogue

Three sequential lessons of approximately 40 minutes were audiotaped for each class. These lessons were predominantly teacher-directed in that science content was given by the teacher and then checked for understanding through the teacher either questioning students or responding to student questions and/or statements. Such lessons qualify as mainly "whole class interactive" as described by Doyle (1983). This mode of classroom activity is where target students have most often been identified (Gallagher and Tobin, 1987). All lessons occurred in a standard six-bench science laboratory and since students were allocated to permanent seats by school policy, it was possible to identify all students.

(b) Other Data

The personality, motivational and cognitive characteristics of students along with their perceptions of the science classroom learning environment were collected by questionnaire. The variables, their definitions and the measuring instruments used are summarized in Table 1.

Table 1 Definition and Measurement of Student Characteristics

Variable	Description	Measuring Instrument
"P" Variables:		
Conceptual Level	Individual differences in social cognition within a framework of developmental maturity	Interpersonal Topical Inventory (Tuckman; 1964)
Locus of Control	Perception of the influence of self and others on own behaviour	Intellectual Achievement Responsibility Questionnaire (Crandall, Katkovsky and Crandall; 1965)
Formal Reasoning Ability	Ability to process information in the absence of concrete props	Bond Logical Operations Test (Bond; 1976)
General Scholastic Aptitude	Ability to cope with educational environments	Test of Learning Ability (ACER; 1974)
"E" Variables:		
Curriculum	Introductory concepts on solutes, solvents and solutions	Water Solutions (Stannard and Williamson; 1979)
Learning Environment	Perceptions of five psycho-social characteristics of the learning environment 1) personalization 2) participation 3) independence 4) investigation 5) differentiation	Individualized Classroom Environment Questionnaire (Rentoul and Fraser; 1979)

Analysis Procedures

(a) Analysing the Interactions

The definitions of target students used in this study are those of Tobin and Gallagher (1987) viz. students selected by the teacher (henceforth called Type 1) and those who involve themselves by raising their hands or calling out (Type 2). The classroom interactions were classified for "teacher to student" as either task, behavioural or organizational and for "student to teacher" as either initiating or responding. A rationale for this classification is given elsewhere (Dart and Clarke, 1988). Analysis of the transcripts of the lessons gave for each student

(i) the number of student responses to questions directed specifically to them by the teacher and

(ii) the number of student initiations or responses to questions asked to the whole class.

These clusters of interactions (i) and (ii) allow the identification of Type 1 and Type 2 target students respectively. From this data, the frequency of (i) and (ii) above was determined for each student along with the mean and standard deviation of (i) and (ii) in each class.

(b) Identifying the Target Students

Previous studies have identified target students through classroom observation and teacher and student nomination. The criterion used here was that students' scores for (i) and (ii) had to be at least 1 standard deviation above the class mean of (i) and (ii).

(c) Identifying the Characteristics of the Target Students

The mean and standard deviation of conceptual level, locus of control, formal reasoning ability and the students' perceptions of their learning environment were obtained for each class (Note 1). The mean scores of the target students on each of these measures were compared with the class means. For consistency with (b), a deviation of at least 1 standard deviation should be used. However, to allow comparisons with previous research, variations of at least 0.5 standard deviations will be considered (Note 2). Both cutoffs are presented in the results which are shown in Table 2 (Type 1) and Table 3 (Type 2).

Table 2 Characteristics of Type 1 Target Students

Variable	Class 1		Class 2		Class 3		Class 4	
Number (Sex)	5 (3F,2M)		3 (2F,3M)		4 (1F,3M)		3 (0F,3M)	
	>0.5 SD	>1.0 SD	>0.5 SD	>1.0 SD	>0.5 SD	>1.0 SD	>0.5 SD	>1.0 SD
Conceptual Level	-	-	-	-	-	-	0.67	-
Locus of Control	-	-	-	-	-	-	-	-
Formal Reasoning	-	-	0.79	-	0.51	-	-	-
Schol. Aptitude	-	-	0.87	-	0.59	-	-	-
Personalization	-	-	0.63	-	-	-	-0.72	-
Independence	-	-	-1.11	-1.11	-	-	-0.78	-
Differentiation	-	-	-0.81	-	-	-	0.82	-
Investigation	-	-	0.88	-	-	-	-	-
Participation	-	-	1.00	1.00	1.03	1.03	-0.76	-
Achievement	-	-	0.56	-	-	-	-	-

Table 3 Characteristics of Type 2 Target Students

Variable	Class 1		Class 2		Class 3		Class 4	
Number (Sex)	4 (4F,0M)		4 (2F,2M)		5 (2F,3M)		5 (1F,4M)	
	>0.5 SD	>1.0 SD	>0.5 SD	>1.0 SD	>0.5 SD	>1.0 SD	>0.5 SD	>1.0 SD
Conceptual Level	-	-	-	-	-	-	0.55	-
Locus of Control	-	-	-	-	-	-	-	-
Formal Reasoning	-	-	0.58	-	-	-	-	-
Schol. Aptitude	-	-	0.53	-	-	-	-	-
Personalization	-1.18	-1.18	0.60	-	0.70	-	-	-
Independence	-0.69	-	-1.04	-1.04	-	-	-0.54	-
Differentiation	-0.54	-	-	-	-	-	-	-
Investigation	-0.62	-	-	-	-	-	-	-
Participation	-	-	-	-	0.82	-	-	-
Achievement	-	-	-	-	-	-	-	-

RESULTS AND DISCUSSION

Some General Points about Target Students (Previous research outcomes are shown in parentheses)

1. Both types of target students were identified in each class with the number ranging from 3 to 5 (previous research: 3 to 5/7).

2. There were approximately equal numbers of each type of target student - 15 Type 1 and 18 Type 2 in 4 classes. 9 of the 33 target students identified were both Type 1 and Type 2, an overlap of 27.3% (52 out of 139; 37.4%).

3. The male-female ratio of target students was, for Type 1, 9:6 or 1.5:1 (44:18 or 2.4:1) and for Type 2, 9:9 or 1:1 (42:11 or 3.8:1).

4. The male-female ratio of target students for male teachers was, for Type 1, 3:5 and Type 2, 1:3. For female teachers, the ratio was, for Type 1, 6:1 and Type 2, 7:3 (no significant cross-sex relationship).

The major differences between the results here and previous research findings are in the gender area. Male students do not dominate and there is a significant cross-sex teacher-student interaction effect. Male teachers chose more female students and female teachers more male students (Type 1); female students initiated more interactions with male teachers and male students initiated more interactions with female teachers (Type 2).

Characteristics of Target Students

The previously identified characteristics of target students regarded as significant are personal ones. They, compared to other students, tend to be higher achievers, have higher levels of formal reasoning ability and a more internal locus of control. The personal and environmental characteristics of the target students in this study are summarized in Tables 2 and 3 where the cutoffs of ≥0.5 and ≥1.0 standard deviations are shown. There is no common pattern of characteristics across all classes in either Type 1 or Type 2 target students. It has not been possible to replicate in this study the earlier findings.

By looking at each class separately however a number of significant findings emerge:

1. In some classes, the target students, irrespective of Type, exhibit little or no distinguishing characteristics from the other students.

2. Only in Class 2 (Types 1 and 2) and to some extent in Class 3 (Type 1) do some of the characteristics previously identified as important emerge (at the ≥0.5 standard deviation criterion). However, in these

different classrooms, these personal characteristics are associated with different environmental perceptions.

3. The only characteristics that emerge as important when the ≥1 standard deviation criterion is applied are the student perceptions of their classrooms.

4. There is more commonality between the different types of target students within a particular class than there is among the same type of target students across classes.

A number of further specific statements could be made. However, these would be about particular types of target students in particular classrooms and each would be different. For example, the students in Class 1 who initiate interactions with the teacher (Type 2) may be doing so out of frustration because they perceive their classroom as one that is unfriendly (-ve personalization), does not encourage enquiry (-ve investigation) but insists on conformity (-ve independence; -ve differentiation). However, the Type 2 students in Class 3 however may well feel encouraged to initiate interactions because they perceive their classroom as one that is friendly (+ve personalization) and encourages involvement (+ve participation). In sum, the most significant finding of this study is that the characteristics of the same type of target students vary from classroom to classroom. The reasons teachers select students or students choose to become involved in interactions in a classroom are idiosyncratic to that particular classroom.

METHODOLOGICAL DIFFERENCES BETWEEN THIS AND PREVIOUS RESEARCH

Earlier studies have defined Type 1 and Type 2 target students and then identified them through classroom observation and teacher and student nomination. The identification process used here is a purely quantitative and arguably more objective approach derived logically from the original definitions. By stipulating the criterion of 1 standard deviation above the mean number of interactions for each class, those students who are in fact either called on most often or volunteer most often are clearly identified. Possible limitations of this approach are first that the 1 standard deviation cut-off may be too arbitrary and second that there is no supporting qualitative evidence available. However, if the task is to identify those students who receive a disproportionately higher number of interactions, different methods of achieving this should produce the same students.

CONCLUSION

The aims of this study were to replicate existing target student research and to investigate the possible contribution student perceptions of their classroom environment could add to existing research findings. Although target students of the types previously identified were found to exist, and found in similar numbers, there the similarity with previous findings ceased. They were not dominantly male and there was a cross-gender relationship with the teacher. The inclusion of student perceptions of their classroom environment did add to the personal characteristics in helping to describe target students. However, their characteristics were not consistent across classes, and although a rationale could be developed to explain the existence of the different types of target students in classrooms, these explanations were idiosyncratic to particular classrooms. The findings in this study would suggest caution in making generalizations about the characteristics of, and rationales for, target students in Year 8 science classrooms.

REFERENCES

BOND, T. (1976) Bond's logical operations test. Townsville, Townsville College of Advanced Education.

CLARKE, J.A. (1987) The influence of the content and structure of curriculum materials and dialogue on achievement in science. Unpublished doctoral thesis, University of Queensland.

CLARKE, J.A. (1988) Classroom dialogue and science achievement. Research in Science Education, 18, 83-94.

CRANDALL, V.C., KATKOWSKY, W. & CRANDALL, V.J. (1965) Children's beliefs in their own control of reinforcements in intellectual academic achievement situations. Child Development, 36(1), 91-109.

DAHLLOF, U. (1971) Ability grouping, content validity and curriculum process analysis. New York, Teachers College Press.

DART, B.C. & CLARKE, J.A. (1988) Sexism in schools: a new look. Educational Review, 40(1), 41-49.

DOYLE, W. (1983) Academic work. Review of Educational Research, 53, 159-199.

FRASER, B.J. (1981) Australian research on classroom environment: state of the art. Australian Journal of Education, 25(3), 238-268.

GALLAGHER, J.J. & TOBIN, K.G. (1987) Teacher management and student engagement in the science classroom. Science Education, 71(4), 535-555.

LUNDGREN, U.P. (1972) Frame factors and the teaching process. A contribution to curriculum theory and the theory of teaching. Stockholm, Alinquist and Wiksell.

STANNARD, P. & WILLIAMSON, K. (1979) Exploring science. Volume 1. Melbourne, MacMillan.

TOBIN, K.G. (1988) Target student involvement in high school science. International Journal of Science Education, 10(3), 317-330.

TOBIN, K.G. & GALLAGHER, J.J. (1987) The role of target students in the science classroom. Journal of Research in Science Teaching, 24(1), 61-75.

TUCKMAN, B.W. (1964) Personality structure, group composition and group functioning. Sociometry, 27(4), 469-487.

NOTES

Note 1. In calculating class means, the scores of the target students were included. It would appear that Tobin and Gallagher (1987) do not include them and so their comparisons are essentially "target students vs the rest". Our approach is more conservative with the result that any differences that do emerge can be regarded perhaps with more confidence.

Note 2. Our decision to calculate class means which include the target students' scores means that 0.5 standard deviation is in fact more substantial variation than the similar deviation in previous research (See Note 1).

Research in Science Education 1989, 19, 76 - 85.

"COPING WITH THE MODERN WORLD" THE CONTEXT AND THE DEBATE AT THE AUSTRALIAN SCIENCE EDUCATION PROJECT GUIDELINES CONFERENCE 1970

Rod Fawns

Twenty years ago the Australian Science Education Project was launched. It was the first and the only national Science project to be cooperatively funded by Commonwealth and State governments in Australia. This paper is the first of two that will examine the practical and cultural arguments that shaped the project.

Nigel Bowen, Minister for Education and Science, proposed an old liberal function anew for school science, in his opening address at the ASEP Guidelines Conference, January 1970.

> "Above all I believe the schools must aim to develop in the individual child the ability to cope with his life through providing the opportunity to plan the use of his time and to select activities. It is no good having a secondary school system that produces students who, when they go to the university - a very narrow section of the world - find themselves completely unable to cope with it. Still less, to produce people who come out from schools or universities to a world which is materially very different and presents many more opportunities than the world did say fifty years ago, and find themselves unable to cope with it - going either into a mental home or to alcohol or drugs. There is a lack, I think, at the present time of relating the education sufficiently to the ability to cope with the modern world as we have made it today."

THE CONTEXT

Until 1963, when Prime Minister Menzies announced an unexpected proposal for Commonwealth Secondary Scholarships, and capital grants to the States for building and equipment costs of technical schools, and for facilities for science teaching in secondary schools, he had consistently upheld the constitutional responsibility of the States and opposed direct federal grants to primary and secondary schools (Gill, 1964). The proposed annual grant of five million pounds to build and equip science laboratories in secondary schools was inspired by the Industrial Fund for the Advancement of Scientific Education in Schools, established by a consortium of private school principals and executives of major business corporation (Smart, 1984). The task of implementation fell to Senator John Gorton who was appointed

Minister in Charge of Commonwealth Activities in Education and Research. L.C. Robson, a retired private school principal and secretary of the Industrial Fund, was appointed a consultant (Sherrington, 1984). Within a year Gorton had found that his implementation of the Science Facilities Grant legislation "to improve the quality of the environment of science teaching" had been very well received and was rapidly expanded (Tomlinson, 1977).

After 1963, Gorton's federalist principles defined a strengthened role for the Commonwealth. Fiscal policy rested at the centre. The Commonwealth redistributed revenue according to its perception of specific areas of need. The States allocated resources within the prescribed areas according to their own priorities, the only restriction being that their projects satisfied Commonwealth specifications of standard (Gill, 1964). Later, under Prime Minister Fraser after 1975, the Specific Purpose Grants were to be phased out and replaced by General Purpose Payments for Education.

What began as an expression of interest by John Gorton in Commonwealth participation in curriculum development in 1967, to David Morgan (1967) at the launching of The Web of Life, and later to the STAV Secretary Robert Wilkinson and at the opening of STAV's Science and Industry Exhibition (Gorton 1967), became the first Commonwealth supported curriculum project: the Australian Science Education Project. There was concern in some areas. Henry Schoenheimer, a Monash academic with a background in English teaching, committed to progressive schooling, attacked the Junior Secondary Science Project when it was announced to the House of Representatives in November, 1968. Schoenheimer (1968) claimed that the Commonwealth Government was looking for a cheap solution to teacher shortages by imposing teacher-proof material on a national basis.

Schoenheimer claimed that "it was not true that anything in American or British experience parallels this heavy-handed exercise in monopolisation." David Morgan, asked as Supervising Editor of The Web of Life project of the Academy to advise Malcolm Fraser on a response to the Schoenheimer attack, felt that the substantial grant of federal money made to the J.S.S.P. would not be as good an investment as the government believed or at least have as good an adoption outcome as that being enjoyed by his project (Morgan, 1968).

Doug White's editorials in Lab Talk had explicitly attacked packaged science courses like J.S.S.P. Teacher autonomy from bureaucratic control was a hot Teacher's Union issue in Victoria at that time after what was seen as a resounding victory in the abolition of the external examination system at

Intermediate level. Education bureaucracies were under siege in most States, where major teacher shortages existed, by the early seventies. Teacher shortages, poor qualifications and lack of experience, particularly in science and mathematics, had been highlighted by the Union campaigns in Victoria since 1962 (VSTA, 1962). The prospect of technologising the curriculum had attracted some support from within the Victorian Education Department because at least it suggested solutions to this intractable social problem of teacher shortage which was endemic to all State education bureaucracies. In his efforts to promote Victorian government investment in science curriculum reform, Robert Wilkinson (1963) had indeed indicated that the J.S.S.P. technology was well enough designed to be run by inexperienced science teachers or even by teachers who were not trained in science. In short, the programme could train teachers while it taught pupils. American curriculum technologies were available which claimed to transform teaching in the direction of the individual or scientific autonomy of the pupil. The potential use of curriculum packages for upgrading teaching skills was an attractive element realized by David Morgan (1962) in the achievement of reform of Biology teaching through the Web of Life.

Malcolm Fraser as minister announced in November 1968 that the Australian Science Education Project would be funded cooperatively by three signatory States, Victoria, South Australia, and Tasmania, and the Commonwealth, for the years 1970-74, to the extent of $1.2 million to prepare learning materials for Years Seven to Ten Science (Hansard, 1968). Of the $450,000 provided by the three States, Victoria made the largest per capita contribution and retained the copyright for published material. Essentially, because the Project was funded in this way, bureaucratic accountability of the Project was a complex necessity, particularly in the early policy formulation (Ennor, 1969). It was accommodated and managed financially by the Australian Council of Educational Research in Melbourne.

The purposes of the Australian Science Education Project, as announced by the Commonwealth and the States in 1969, were articulated to participants in advance of the National Guidelines Conference held at the new Monash University in January 1970. The outstanding priority was "to develop instructional materials in Science for use by teachers and pupils in Grades 7-10 in Australian Schools" (Howard, 1969). The production of good junior science materials for general use seemed to the Prime Minister, John Gorton, to be a technical service that the Commonwealth could provide in an area likely to be uncontroversial and to earn popular approval.

The Universities had received sympathetic treatment in the Menzies era. Under Menzies in the fifties, specific grants for the universities had been extended considerably, leading up to his establishment of the Australian Universities Commission in 1959, chaired by Melbourne's Professor of Physics, Leslie Martin. However after Menzies the universities were more likely to be publicly criticized. For example, in one address reported in the Australian in November 1968 Leslie Bury (1968), Minister of Labour and National Service in the Gorton Government attacked the universities for their lack of interest in commerce, particularly their tardiness in setting up post-graduate business schools after the American models. "Education," he maintained, "was left too much to academics." Reported under the heading: "Academics Hinder Business Programs," he said,

> "Australia's inheritance of the British tradition of education - distilled from the monasteries of the Middle Ages - had inhibited economic progress."

Quoting from the London Economist, he agreed,

> "British industry would be in nothing like such a bad way if the ordinary university arts graduate knew a little more about science and a little less about Beowulf."

By the early seventies, the professional interests of the science teacher and the scientist could be more easily differentiated. This sense of independence from academic control related at this time to the social agenda ascribed to education through expanded budgeting provision which in turn related to the size of the industry. This was not a local phenomenon. It can also be related to the emergence of science students as an area of research in Australia.

Government expenditure for education by the States increased from $795.4 million in 1969-70 to $1,360.4 million in 1972-73, an increase of 43.7% in the four year period (Mathews & Fitzgerald, 1975). In such brief periods of apparently sustainable affluence and relative social cohesion, and middle class charity can be extended to the working class. Nigel Bowen addressed education as it had been in the war years as a major instrument of individual adjustment or social adaptation, rather than as an instrument of social selection. Interest in the Life and Social Sciences was growing strongly and strongly influenced the membership and outlook of the project.

Government investment in the Australian Science Education Project provided a popular form for education research as can be seen in the first paper presented at the first ASERA Conference which was established to continue discussion of theoretical issues that arose in the Project. Research in Science Education achieved recognition in appointments throughout Australia in the years of the project 1968-74.

Of the nine academics in residence in January 1970 at the Guidelines Conference of the Australian Science Education Project only two were from science faculties; the others were from education faculties and teacher colleges.

THE DEBATE

At the Guidelines Conference called by the newly appointed executive group, Bert Howard, Les Dale and Greg Ramsay, each of the six states was represented by a Science Inspector or Officer of similar rank from the state's Advisory Committees as well as others from teacher education, teaching and ACER. From the outset, the task of producing something 'useful' in each State was emphasised. The three contributing states had a certain proprietorial interest, particularly Victoria, but the other States had some investment through the Commonwealth.

Whilst developments such as Wyndham decentralization and the *Web of Life* adoption were closely followed and implications discussed at annual meetings of the Directors and Ministers at the Australian Council of Education, independence was jealously defended by each state. In New South Wales the potential value of JSSP and ASEP units in 1970 was severely restricted by commitments to the introduction of Messel's General Science programme under Wyndham. The JSSP unit, the intellectual precursor to the ASEP unit, was introduced by Wilkinson (1969), Merv Turner and Dale to promote attitudes, skills and understanding appropriate to junior scientists; but the unique feature was the individualisation - pupils working at their own rates, assessing their own learning at each stage and undertaking programmed practical work. The individualisation of science instruction was not a feature of the forties reforms which centred on establishing a mass public education in General Science.

From the outset social as well as psychological differences were emphasized at the Guidelines Conference. The perception of the child having a complex social and intellectual identity guided discussion of curricula functions and distance disciplinary claims.

"Compensation" was a catch-cry in the second generation curriculum reforms produced in America under Kennedy and Johnson from the mid-sixties in projects such as the Intermediate Science Curriculum Study (ISCS). Several speakers at the Guidelines Conference spoke of ASEP having compensatory features. Peter Fensham (1970), Professor of Science Education at Monash University and successor to John Turner as Chairman of the Schools Board Science Committee, meant by this:

> "the recognition that educational opportunity is not achieved by simply providing materials and other extra school experiences. Compensatory education means that beyond these the curriculum project takes seriously the different extra school environments and experiences of the children."

The notion of a compensatory education for all students was bound to be misunderstood. Later in the Conference a paper was circulated by ACER staffers Merv Turner and David Bennett (1970), criticizing proposals that had been put by two States that a "compensatory education" should be provided by ASEP for students in lower streams. They argued that this approach to compensation, of providing material at different levels, is often based on the assumption that the pupil's capacity to learn will not change significantly and the Project would do nothing to ensure development. They argued further that such errors in social judgment would be avoided by adopting the Piagetian model of three stages of development.

> We know that 'social-economic' factors are for all pupils the main variable determining initial differences in ability. Therefore, if the Project is in fact based on the philosophy we have outlined (developmental psychology), it would be absurd to add a rider that some special provision should be made for some particular group of children affected by these factors.

Their recommendation was that the Project should emphasise individual psychological rather than socio-economic differences and assess its success in terms of increased participation and retention. The Project, they argued,

> could serve this social purpose, investing considerable effort to provide learning experiences for those pupils who start further back who due to a less fortunate home background will struggle to make the transition to Stage 3 of logical abstract thought, and rational analysis and argument characteristic of science.

The attainment of Piagetian formal operations was seen by Turner to be a new goal in science teaching. It was a logical extension to the JSSP argument for the primacy of scientific method defined in terms of laboratory skills and mental drill which confirmed predetermined order and logical interrelations. The logical training approach seems to have been more attractive to the physical scientists than to others at the Conference, who now had a more elaborate model of scientific enquiry in the Web of Life which seemed to work for a wider range of student ability.

The supporters of the JSSP card system seemed to connect to the disciplinary training of H.E. Armstrong whilst others assumed a view of scientific disciplinary method reminiscent of T.H. Huxley, a common sense reasoning to be applied to everyday phenomena (Jenkins, 1978). Both groups found their uses for Piagetian theory.

Bennett and Turner opposed proposals presented at the Conference by Les Dale which emphasised selecting materials and experiences which were "meaningful," "interesting," "relevant," to the child and within his immediate experience. They argued that these could not be ends in themselves, but merely psychological devices by which to illustrate or illuminate certain theoretical principles. Les Dale and others espoused Piaget's organismic theory of development which suggested learning was a process of assimilation and accommodation, and ultimately internally regulated, rather than the product of Gagnean conceptual engineering. Bennett and Turner (1970) commented:

> The selection of what the child should learn should be determined by many factors, of which the set of logical inter-relationships between the concepts, principles, etc., is only one. Whether the material is interesting, relevant, etc. to the child before he has the learning experience should not be one of these factors. On the contrary, most of the knowledge to be acquired is selected simply because it is not seen as relevant by him, not within his past range of experience. (Incidentally, the notion of providing the child with experiences missing from, and often alien to the culture in which he has been reared is central to the concept of compensatory education - indeed, we believe, to any morally acceptable philosophy of education.)

To them, the position expressed by Dale "had been used to justify the position that pupils do not have to acquire any knowledge which they do not already possess." At least at the level of rhetoric the organismic (means to end) rather than the engineering (ends to means) theory was to prevail, mainly on the States' rights arguments that no one programme would be acceptable. The States, led by Victoria, wanted flexible materials rather than a course or syllabus. In the end the arguments for individualisation from Merv Turner and Robert Wilkinson served to reinforce rather than challenge the Ministry's commonsense equation of social and intellectual with personal development through science.

A final draft of the Aims of ASEP was proposed by Vickery (1970), Convenor of the Western Australian Advisory Committee, for discussion by syndicates at the Conference. The first of the five draft aims is quoted here:

> Science education can and should contribute to the personal development of the individual in aspects of social responsibility and by contributing to the achievement of greater self-reliance, independence, flexibility and creativity. The programmme should embody experiences which lead towards the development of the child as a social being.

Apart from the emphasis on personal development through science in the first aim, the others were reminiscent of those stated in the forties in support of the introduction of courses of General Science (Fawns, 1987). The impact of the application of science on the tranformation of human society and outlook was ignored. Ron Shepherd (1960), one of the Area Specialists appointed to the ASEP Project team, made this point in immediate response to the draft.

> Children live in an environment which has been transformed or created by the application of science and their "science education" could well consist of learning how some of these changes have come about, and developing an interest and concern towards the consequences of the scientific endeavour. In the process of doing this, the child will inevitably learn a great deal of scientific knowledge.

Other critics sought more explicit commitment to "enquiry" and to the needs of the able students.

Syndicated discussion (1970) took each of the Aims in turn. Their final endorsement was a direct challenge to the moral form of the old science texts and schooling in general. The twin values of scientific liberalism, methodogical individualism and freedom of choice were to be materialised in the Project.

Thirty years after the first attempt the notion of a general science course that was more than the disciplinary parts was still implausible. A school science course which integrated scientific and social knowledge was simply inconceivable at this time. A licence to explore the general developmental as well as the elite scientific purposes science education had once again been issued but not the responsibility to choose one or other. At the Guidelines Conference in January 1970 all syndicate groups were able to endorse the Project's democratic agenda of "coping with the modern world".

The Project was able to broaden teachers' perceptions about what was possible in science classes. However with the collapse of economic confidence resulting in the sacking of the Whitlam Government in 1975 the prospects of changing teachers' roles and functions in the direction implied by the Project faded rapidly.

REFERENCES

BENNETT D and TURNER M (1970) A comment on some basic issues. Paper circulated at the Guidelines Conference.

BURY L (1968) Minister of Labour and National Service, *The Australian* November 8.

FENSHAM P (1970) Implications from other Curricular Development Proposals for Curricular Development in Australia. Paper presented to the Guidelines Conference, January.

ENNOR H (1969) Letter from Secretary of Department of Education and Science to J S Turner Turner Archives, Melbourne University.

FAWNS R (1987) *Maintenance and Transformation of School Science* unpublished PhD, Chapters 1 and 10.

GILL P (1964) The Federal Science Grants Scheme in Edgar French Ed. *Melbourne Studies in Education* M.U.P.

GORTON J (1967) An Australia Science Policy, *Lab Talk*, August.

HANSARD (1968) HOUSE OF REPRESENTATIVES, October - November.

HOWARD H (1969) Letter to paricipants to the Guideline Confernce, Australian Science Education Project - Its Purposes, December 2.

JENKINS E (1978) *From Armstrong To Nuffield* Murray London

MATTHEWS J and FITZGERALD R (1975) Educational Policy and Political Platform, The Australian Labour Government. *Australian Educational Review* 7 April.

MORGAN D (1967) Letter to Bill Meyer (BSCS) 20 March 1967, Turner Archives M.U.

MORGAN D (1968) letter to Rutherford Robertson, Turner Archives M.U. 15 November.

MORGAN D (1969) Some Secondary Science Curricular Developments in Australia. Addressed to the Pacific Science Conference, Kuala Lumpur, May.

SCHOENHEIMER H (1968) The Australian 4 November.

SHEPHERD R (1970) Views on the Aims, circulated paper at Guidelines Conference.

SHERRINGTON G (1984) The Headmaster in Cliff Turney Ed. Pioneers in Australian Education Volume 3.

SMART D (1984) The Industrial Fund: A Highly Succcessful Model of Big Business collaborating with the Headmasters' Conference in the Interest of School Science. In Stephen Murray Smith ed Melbourne Studies in Education MUP.

Syndicate Reports (1970) Comments on Aims First Draft, circulated paper at Guidelines Conference. In Fawns 1987 op.cit.

TOMLINSON D (1977) The Liberal Party: Politics and Education Policy, Australian Education Review 8. ACER.

TURNER M (1970) The Contribution of J D Bernal to learning and instruction. Paper circulated at the Guidelines Conference.

VICTORIAN SECONDARY TEACHERS ASSOCIATION (1962) Staffing crisis in Victorian Secondary Schooling

VICKERY R (1970) The Aims of ASEP First Draft. Circulated paper

WHITE D (1967) Editorial Viewpoint Labtalk, June.

WILKINSON R (1963) Conversation with Fred Brooks Director General of Education in Fawns R. The Maintenance and Transformation of School Science. op. cit. Chapter 1 p 47.

WILKINSON R (1967) Submission to Senator J G Gorton Minister for Education and Science 27 September. Turner Archives, Melbourne University.

Research in Science Education 1989, 19, 86 - 96.

EDUCATION AND SCIENCE - THE STATE OF THE UNION

H. Fearn-Wannan

THE BRAIN DROUGHT IN AUSTRALIAN SCIENCE

> "Today's young people are seeing security in those professions which regulate rather than those that are creative and entrepreneurial." Pennington (1989).

Recent media attention to the present plight of Australian Science has highlighted two important issues which have serious long-term implications for the Australian economy.

The first is the well-established "brain drain" in which many of the best and brightest of the research men and women of Australian Science have been forced by lack of opportunity and resources to seek employment in overseas companies and universities. The lack of venture capital within Australia and the traditional view of industry in this country that research training and post-graduate experience is largely the responsibility of the university, have combined to produce a climate of rejection for many of our young Science graduates. The long-term result of this "graduate haemorrhage" is patently obvious. Australian industrial myopia and governmental thrift in this respect have inevitably led to a shrinkage of our "intellectual stock". It is to be hoped that recent government commitments to bolster funds for scientific research will help to arrest this dangerous trend.

Despite all of this, it has to be recognised that Australian science is by no means redeemed by this single action on the part of the federal government. For, sapping the strength of the scientific productivity of this country like an intellectual cancer, is the "brain drought" to which Pennington (1989) was referring. There is a dissatisfaction with science in the classrooms and lecture theatres of this nation - a dissatisfaction which is leading to a significant swing of student interest away from the Sciences toward what Pennington called the "regulatory professions". This swing manifests itself in the lowering of entry standards into the Science faculties of the universities which have occurred over recent years.

Commenting upon the recent government financial stimulus to Australian Science, Gardner (1989) has alerted the Australian scientific community to the fact that the government has addressed only one part of the problem confronting Australian science, i.e. the "brain drain". As he has put it, "Canberra seems to think that the way to improve scientific research is to inject finance into the post-graduate end of the system". Gardner points out that "this belief rests on a crucial assumption: that our most promising budding scientists are steadily moving through the school and university system; all that is now needed is financial support for their subsequent research". He reminds us that young people need to be encouraged early by means of a stimulating and interest-generating science program at the primary school level where "the foundations of children's interests in science are established".

Interest in and enthusiasm for science, the basis of career decision-making, appear to be lacking in many young Australians today. Somehow the fascination and satisfaction of science as a way of thought and action, and ultimately as a professional option, are missing from the experience of many Australian boys and girls in the career-choice years.

CURRICULAR FAILURE

The launching of the first Soviet satellite, Sputnik, in August 1957 was indeed one of the most significant pebbles to be dropped into the pond of Western experience. The ripples are still evident, at least in the educational world, despite the passing of three decades.

The Australian reaction in the late sixties was the Junior Secondary Science Project, and in more recent times there has been a reshaping of the primary Science curriculum with programs such as the Victorian "Science in the Primary School" and the "Science Frameworks".

Sad to say, neither the international nor the Australian curricula appear to have been adopted as widely as was hoped. Writing in the Times Educational Supplement (2/5/80), Virginia Makin reported the results of a survey of 3000 British primary school children. She found that Science, where it was taught, was by far the most popular subject. However in most schools it was not being taught to any significant extent. "It would be impossible", writes Makin, " to exaggerate the enthusiasm for primary Science where it happens, and the strength of the demand for it where it does not."

According to Skamp (1982), surveys in Britain and the United States reveal the continuing Cinderella status of primary Science education in those countries. There is every reason to believe that the same is true in Australia. As already indicated there was a keen interest in Science education from the curriculum developers of the Ministries of Education in several states. Miller (1984) spoke of the task of the Science teachers as being "to bring Science down from its pedestal, or at least to bring it out of the realm of the laboratory ...... We need to show people that the manner of thought and the intellectual attitudes which are part of this approach to Science have a general and vital application to their lives." However the attempt to popularise science by the "Science for all" approach has not been particularly successful either. The Curriculum Branch of the Victorian Ministry of Education (Schools Division), which was responsible for the production of Science Framework P - 10 (1987), frankly admits that the primary Science programs of the past have fallen short of the "Science for all" aspirations:

> There has been a growing unease among primary and post-primary teachers and a desire for a curriculum that is more relevant, more useful, and communicates to a wider group of students. It is time for a revised Science curriculum framework.

A similarly disappointing assessment comes from Queensland. In their Preliminary Report of an investigation into pupils' Learning of Science in Primary Schools, Cranston and McAllister (1988) pointed out that the early emphasis in the primary Science project initiated in 1975 was on the development of a series of in-service teacher education modules. They identified five essential elements to the Science program: process skills, manipulative skills, positive attitudes, concept development, and "hands-on" activities. Thirteen years later Cranston and McAllister reported that:

(1) Writing, class discussion, listening and talking were the major activities in Science classrooms in Queensland.

(2) Girls reported less "hands-on" experience in Science than did boys.

(3) There was no great desire "to be a scientist when I grow up" expressed by the children.

(4) Girls were more positive than boys about their interest in Science at grade 5, but this had been reversed by year 7 - a subtle motivational shift.

In summary it would appear that, despite the general upgrading of Science programs in Queensland primary schools, there has not been a significant lifting of the interest level and achievement of primary children in Science learning, particularly amongst girls. One would suspect the same to be true of the other Australian states.

The vital importance of this aspect of primary Science was the focus of an address given by Kwong Lee Dow (1989).

> The reality is that the decisions about careers in Science that appear to be made by young people can in fact be tracked down to the formation of attitudes, and the setting of priorities and aspirations many years earlier. It is the sustaining of a sense of interest and lively enthusiasm, and the formation of positive attitudes, and the fact that these young people are going to feel comfortable and confident about these fields, which determine their future.

Many children are completing the early years of Science education, it seems, without the desired grasp of the principles of Science, nor with an enthusiasm for Science which would spur them on to higher studies in the field. Something has gone wrong, and there is an urgent need for corrective action.

REASONS FOR FAILURE

(A) A lack of mental rigour.

One of the most frequently heard criticisms of Australian education in recent years has been that schools have been neglecting their primary purpose, that of developing their students' mental powers to the full.

In contemporary Australia educational crusaders such as Leonie Kramer, Lauchlan Chapman and others have called for a return to academic rigour in our schooling. Employers and academics alike are aware of a lack of basic mental skills in many of the young people graduating from high school, and the call has gone out for a movement in the direction of the more rigorous. albeit narrower, education of a bygone era.

With respect to Science in schools, this loss of mental rigour is associated with an apparent devaluation of the level and scope of Scientific theory in the curricula, and the relative lack of emphasis on precision and accuracy in the laboratory.

(B) A lack of relevance and excitement.

Although attempts have been made to redress the irrelevance question by the introduction of the "Science for All" philosophy, the excitement of actually doing Science is frequently absent because there has not been a sufficient development of an effective "hands-on" approach to the learning of Science, particularly in the primary schools of the nation. Despite the aforementioned effort that has been expended at both primary and junior secondary levels, the "brain drought" persists in Australia.

(C) A lack of adequate reward.

A lack of an adequate professional reward either as resources for post-graduate and later-career research or as salary has already been alluded to, but is a significant factor contributing to this unhealthy state of affairs. A change of heart by both industry and government is urgently needed in this country. In comparison with that of a country like Canada, Australian institutional support for Science, despite recent changes, is miniscule.

(D) A lack of in-depth Science training.

The primary school input is still relatively deficient as a consequence of the lack of in-depth Science training for student teachers. It is not surprising, therefore, that a majority of primary school teachers lack both a keen professional interest in Science, and a feeling for its thought patterns. Thus the class lessons and labs are more often than not taken without reference to the philosophy, the rigour, or the relevance of Science.

A study of the literature reveals that the same problems exist in Australian schools as are evident in the teaching of primary Science internationally. Skamp (1982), for example, expresses the view that there would appear to be no significantly different factors present in the Australian scene to suggest that the solution to the problems of K - 6 Science in Australia has been found. Skamp lays the blame for this state of affairs at the feet of primary Science education.

Kleinman (1965) made the same point about American pre-service education, and pointed out that the inadequate scientific background of the great majority of primary teachers leads to a fundamental insecurity, lack of interest, and a reticence to teach Science.

(E) The masculine image of Science.

Another factor is the failure of Science, particularly at the primary and junior secondary levels, to appeal to girls. Arguably this is the essential cause of the gender differences which are apparent in tertiary Science education. It is contended by some that the traditional Science syllabus is male-oriented, that teacher interaction with girls does not encourage creativity and enquiry to the same extent as it does for boys, and that girls' potential in Science is still being limited by a deeply entrenched gender-stereotyping. When Jack and Jill went up the hill to fetch a pail of water and had that unfortunate accident, why was it the Jill had to come tumbling after? Why didn't she set the pace?

(F) The lack of a basis in educational theory.

A problem encountered at all levels from primary to tertiary is that teaching programs are usually offered as "seat of the pants" curricula; i.e. rarely tied to any well-recognised educational theory of learning. And so there is very much a trial and error approach to the teaching of Science with no certainty that the espoused aim is ever achieved (uncertain effectiveness) or achieved at a high level of competence (doubtful efficiency).

(G) The mathematical bogie.

David Suzuki (1988) claims that a lack of confidence in Mathematics turns many people, particularly girls, away from Science.

> Children are being taught very early in schools, and disproportionately the girls absorb this message, that if you can't do Maths, you can't do Science. By the time the kids get to high school the vast majority have been turned off Science because Maths is an enormous barrier that prevents access to Science.

There is obviously a great need for an interest-generating, minimally-quantitative Science to be presented to children as early as possible so that the interest is captured well before the Maths bogie raises its head. The rationale is that the early fascination of Science will stimulate the child to acquire mathematical competence as a useful tool to enable the pursuit of his or her scientific interests.

THE CONSEQUENCE AND A SOLUTION

The interaction of these problems, i.e. lack of rigour, excitement, prospect, teacher confidence, female-friendliness, basis in theory, and the Maths bogie has produced a situation in which Science, particularly in the primary school, has been impoverished. Without these stimuli the child's scientific imagination and mental satisfaction are dissipated to the ultimate detriment of the national scientific enterprise. A "brain drought" is the logical outcome for Australian Science.

The problem it would seem cannot be solved unless many more Science graduates are prepared to become involved in the teaching of Science to primary school children. Given that, for a range of reasons, this is a highly unlikely scenario in the present economic and social climate, a compromise has been suggested by Virginia Makin (1980): the hiring by schools of primary Science consultants.

Such consultants would need to be Science graduates with considerable experience in Science teaching, e.g. retired Science teachers and lecturers. This concept has been operating across the United States of America for some years, and is well accepted because of the excellent results it achieves.

Reinisch (1966) extolled the virtues of Science consultants in primary schools: "The elementary school has a real need for people who have substantial knowledge of Science to guide the program at this level." His view was in line with that of the American Association for the Advancement of Science and the American Association of Colleges for Teacher Education (1960):

> Science consultants should be employed to assist elementary school teachers, as most of them will not have had adequate preparation for the kind of Science teaching here envisaged.

Blackwood (1965) went even further in claiming that a "lack of consultant services has been indicated by schools as a most important barrier to good Science teaching."

In a study of the role of Science consultants, Richardson (1963) stated that "elementary school Science consultants generally seemed to stimulate Science programs", and that "the desirable consultant role seems to be that which assists, guides and motivates the regular classroom teachers to lead the Science teaching facets of the curriculum."

Harty (1976a, b) and Mahan (1972) made studies of Science consultant performance. Some of their conclusions were that:

(1) classroom verbal behaviour of teachers is improved when consultants are used.

(2) teachers who have interacted with consultants are less dependent upon the prescribed curriculum.

(3) teachers regard the consultant's wide knowledge of Science as the

(3) teachers regard the consultant's wide knowledge of Science as the most important facet of their contribution.

The primary Science consultant can contribute valuable assistance to the classroom teacher by helping to plan and run the labs, recommend references and other resource people, provide a socially-supportive context in which girls particularly seem to thrive academically, or even conduct Science labs. with the teacher as assistant. By adding vitality to the classroom environment, the consultant can facilitate stimulating and meaningful learning. From time to time one hears it said that the fundamental interest in Science which lies at the heart of the successful professional scientist was laid down in the early school years by a visionary teacher. But this experience is all too rare.

The implementation of such a program will inevitably encounter certain difficulties. Perhaps foremost would be the winning of the confidence of the classroom teachers. Many of them have admitted to feelings of inadequacy, but the suggestion that they need help may well have a negative reaction. Ideally teachers would seek to join such a program of their own volition. The manner of its promotion in schools will be of utmost importance.

A second anticipated difficulty will be the convincing of school administrations of the importance of Science in the curriculum. The arguments set out earlier may be effective.

Finding sufficient qualified consultants may prove difficult. Ideally members of staff with a background in Science would act in this capacity. But as these people are rare in Australian primary schools, the use of retired scientists with a flair for communicating Science to young children should be considered.

Finally, the inevitable problems of financing the program would have to be considered. Gardner's (1989) call for the infusion of government resources into the teaching of Science to primary school children is highly significant in this context.

If it is accepted that there is a need to upgrade the teaching of Science in primary schools in order to stimulate interest in Science before entry into secondary school, and if the inadequacy of the pre-service Science training of most primary teachers is acknowledged, then the desirability, even necessity, of Science consultants in Australian primary schools must be entertained.

The ideal situation would be for senior scientists with some teaching background to liaise with primary teachers to assist in the production of Science labs for the normal primary classroom, and even to be involved as members of the teaching team. By the skilled use of such experienced people an enormous amount of enthusiasm for the study of Science in a rigorous manner could be generated amongst our girls and boys.

Malcolm Rosier (1988) describes the mediocrity of the current state of Australian Science by reporting on the Second International Science Study which was conducted under the auspices of the International Association for the Evaluation of Achievement (IEA).

> "On Science tests given to comparable samples of students at upper primary and lower secondary levels, the performance of Australia was close to the international mean for the countries in the report. At the lower secondary level the relative performance of Australia has declined since 1970."

Rosier goes on to point out that one possible reason for the differences may lie in the content and structure of the Science curriculum. Most of the countries have Science curricula that are prescribed, to a greater or lesser extent, by national authorities. All students systematically cover a range of content as they proceed through the different stages of schooling. By contrast most of the responsibility for the decisions about the content of the Science curriculum in Australia has been assigned to individual schools. Under a decentralised system some students may fail to receive systematic exposure to an adequate range of Science content and process.

These results represent the only information available to enable Science educators in Australia to assess their activity from an international perspective. This is of particular importance if Science education is to contribute to the country's national development in an environment where there is increasing pressure on Australia to lift its economic performance relative to other countries.

It would seem therefore that a prescribed curriculum designed by scientists who have a teaching background and a concern for effective teaching in the basics of Science is long overdue.

REFERENCES

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE and the AMERICAN ASSOCIATION OF COLLEGES AND TEACHER EDUCATION.(1960) Improving Science and Mathematics Programs in American Schools. Report of the Joint Commission on the Education of Teachers of Science and Mathematics. Washington, D.C.

BLACKWOOD, P.E. (1965). Science teaching in the elementary schools. U.S. Department of Health, Education and Welfare Circular No. 749. Washington, D.C. U.S. Government Printing Office.

CRANSTON, N., & McALLISTER, R. (1988). A preliminary report of an investigation into pupils' learning of Science in primary schools. Department of Education, Queensland.

GARDNER, P.L. (1989). Boost for Science must start with primary school children. The Age, 13/5/89.

HARTY, H. (1976a). Involved educators assess the importance of consultant activities during the implementation of an innovative curriculum. School Science and Mathematics, 76, 97-106.

HARTY, H. (1976b). The implementation consultant and classroom teacher-pupil verbal interactions. Science Education, 60(1), 39 - 46.

KLEINMAN, G. F. (1965). Elementary school Science consultants. School Science and Mathematics, 65(8), 738 -743.

KWONG LEE DOW (1989). Speech on the occasion of the opening of Carey Donvale; 24 February, 1989.

MAHAN, J. M. (1972). Using teacher questions to look at Science consultant performance. Science Education, 56(3), 329-336.

MAKIN, V. (1980). Primary Science. Times Educational Supplement 2/5/80.

MILLER, R. M. (1984). Science teaching for the citizen of the future. Science Education, 68(4), 403 - 410.

MINISTRY OF EDUCATION (SCHOOLS DIVISION) VICTORIA. (1987). The Science Framework P - 10.

PENNINGTON, J. (1989). Radio Broadcast - Occam's Razor. A.B.C.; 22/3/89.

REINISCH, B. (1966). The need for Science consultants. Science Education, 50(1), 52 - 54.

RICHARDSON, E.C. (1963). Proposals for improvement of Science teaching in New Jersey elementary schools. Science Education, 47(3), 299 - 303.

ROSIER, M. (1988). International comparisons of Science achievement. Unicorn, 14(2), 112 - 117.

SKAMP, K. (1982). Primary Science in the eighties. Unicorn 8(1), 44.

SUZUKI, D. (1988). On Science, growth and human beings. Investigating APS J. 4(3) 4 - 7.

Research in Science Education 1989, 19, 97 - 110.

CATEGORIZING PUPILS' EXPLANATORY FRAMEWORKS IN ENERGY AS A MEANS TO THE DEVELOPMENT OF A TEACHING APPROACH

M. Finegold and R. Trumper

A number of studies (Gilbert and Pope, 1986; Bliss and Ogborn, 1985; Duit, 1984; Watts, 1983) have aimed at presenting as complete a picture as possible of the range of pupils' ideas about energy. We report here the findings of a pilot and case study in which we identify and categorize students' alternative explanatory frameworks on energy, with the aim of developing a teaching approach which can narrow the gaps between student frameworks and those acceptable to the science community.

THE PILOT STUDY

A series of five energy related tasks, the first four of which were taken from Duit (1984), were administered to 175 students, using the interview-about-instances technique developed by Osborne and Gilbert (1980). In this technique students describe examples or non-examples of the physical concepts and situations presented in a series of pictures. The student sample, taken from secondary schools in northern Israel, comprised: 75 grade 9 students who had had no previous instruction in physics; 29 grade 10 students who had studied a one year programme 'Energy and its transformations' (1978); 18 grade 11 students some of whom had taken physics previously and who were about to start a course in mechanics; and 50 12th graders all of whom had studied physics, including mechanics.

The five tasks required the students:

(1) to write down their first three associations with the word energy;

(2) to define or describe the meaning of the word energy;

(3) to write down three examples of the concept of energy;

(4) to predict the height reached by a ball released on a frictionless roller coaster, and to explain the prediction; and

(5) to select three out of fifteen pictures in which they identified the energy concept, to select one picture in which the energy concept did not appear, and to explain the four selections.

In the following we report on the analyses of responses to tasks 2, 4 and 5 which provide information directly related to the aim of categorizing students' explanatory frameworks. Responses to tasks 1 and 3 are not reported here. Task 1 does not bear directly upon the issues discussed in this paper and task 3 was dropped from the revised questionnaire since it was not found productive.

Definitions of energy (Task 2)

This task called for definitions or descriptions of energy, which were classified according to the following listing of alternative descriptive frameworks (a modification of that by Watts, 1983):

1. Anthropocentric- associating energy with human beings;
2a. Depository- some objects have, and expend energy;
2b. Active deposit energy causing or needed for things to happen,
3. Ingredient- energy as dormant in objects and released by a trigger;
4. Activity- in which energy is an obvious activity;
5. Product- energy as a product of a process or a situation;
6. Functional- energy as a 'kind of fuel';
7. Transfer- energy as "something" transferred in an interaction or process.

We classified almost all student definitions with frameworks 2a, 2b & 7 being used more frequently than the others. Thirty six percent of the students used 2 or 3 alternative frameworks. (see Figure 1).

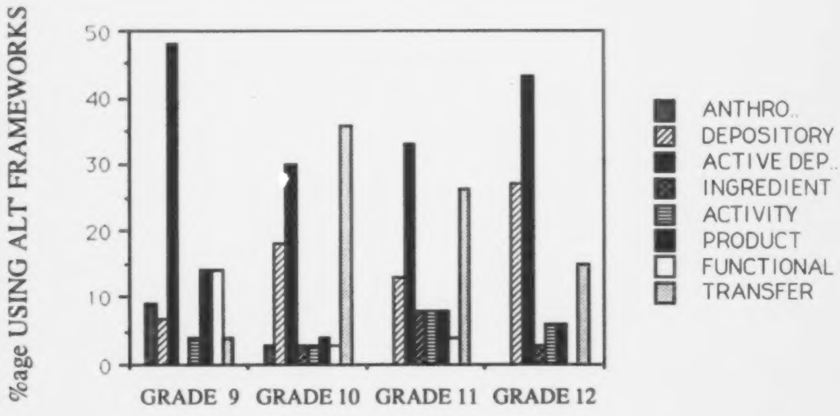


FIGURE 1 DISTRIBUTION OF ALTERNATIVE EXPLANATORY FRAMEWORKS USED BY STUDENTS. BY GRADES, IN PERCENTAGES

Prediction of a mechanical process (Task 4)

This task followed students' explanations about a mechanical process involving conservation. The case chosen was that of a ball released on a roller coaster. Students predicted and explained the position the ball would reach. Responses were expected to reflect differences in the physics programmes followed by the various grade levels. Energy and the principle of conservation are taught in grades 9 and 11. The number of students answering correctly, and using the concept of energy or the principle of conservation, increased after grade 9, decreased from grades 10 to 11, and increased again after grade 11. However, while 66% of the grade 12 students answered correctly, only 56% used the energy concept in their explanations and only 38% used the concept of conservation.

The identification of 'energy situations' (Task 5)

Students selected 3 of the pictures shown in Figure 2, in which they could best identify energy, and explained their selections.

Figure 3 presents the distribution of student choice of pictures. The pictures of the statue and the room were not chosen at all and therefore are not shown. Ninety three percent of students' explanations were found classifiable by the alternative frameworks used in classifying responses to task 2. The most commonly used framework was the active deposit(2b) used by 39%. The anthropocentric framework (1) was used by 21%, transfer (7) by 18%, product (5) by 13%, and depository (2a) by 8% of the students. Each of the other frameworks was used by less than one percent. This task also required students to choose a picture in which the energy concept did not appear. Sixty five percent chose the statue, 30% the room, less than 1% found no such picture, and less than 1%, all in grade 9, chose the girl eating, the sailing boat, or the hot water. Most of the explanations used phrases like "absence of activity", "no movement", "everything is inert". Such explanations are similar to those reported by Bliss and Ogborn (1985) who commented that "the pattern of selection suggests that animacy is a salient feature with which students identify the concept of energy".

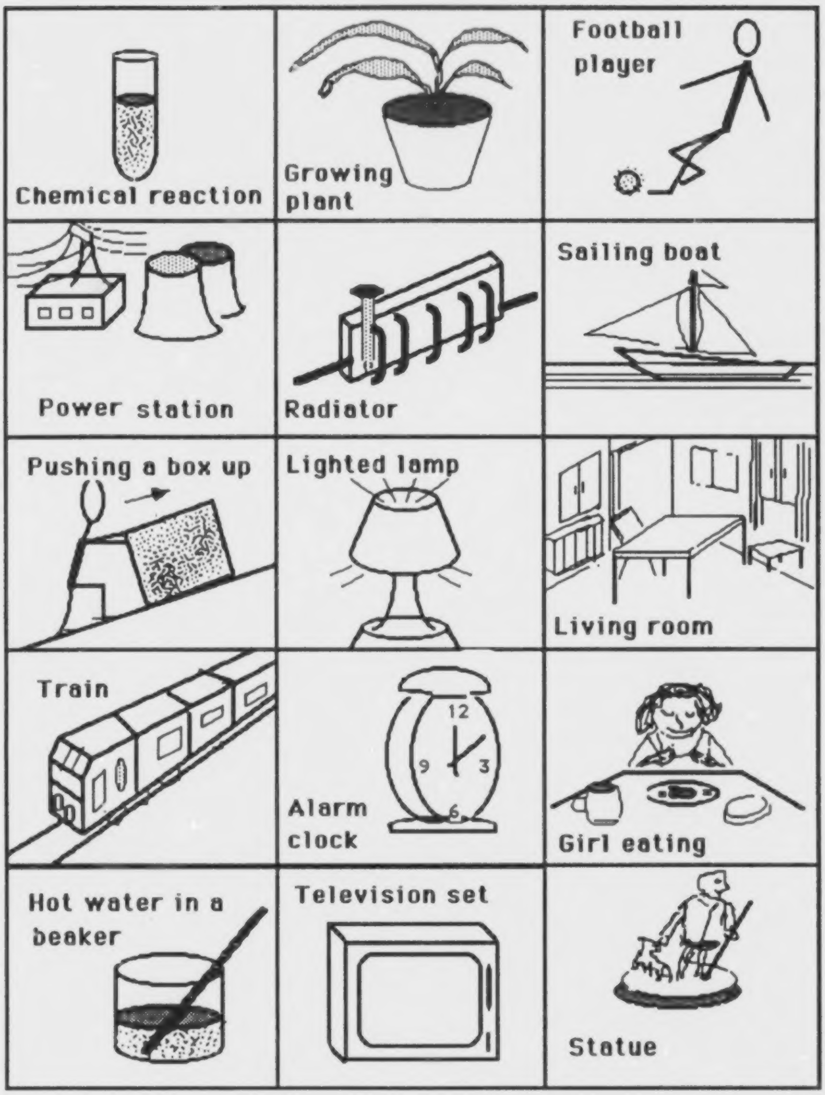

Chemical reaction
Growing plant
Football player
Power station
Radiator
Sailing boat
Pushing a box up
Lighted lamp
Living room
Train
Alarm clock
12
9
3
6
Girl eating
Hot water in a beaker
Television set
Statue

FIGURE 2 FIFTEEN PICTURES

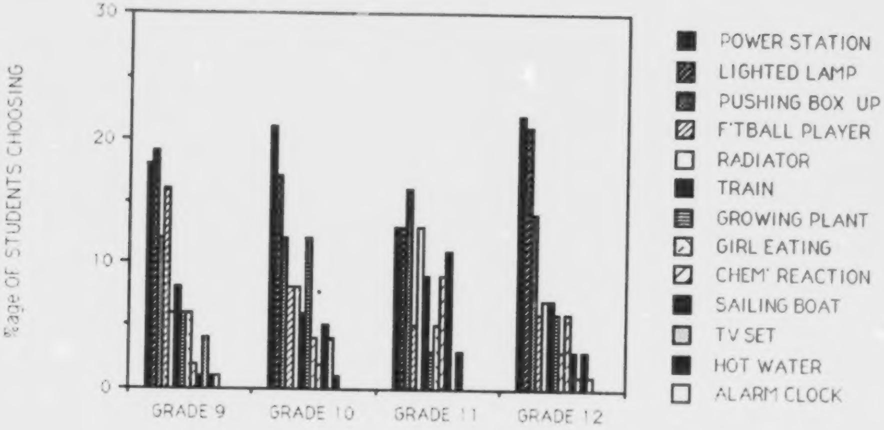


FIGURE 3 DISTRIBUTION OF STUDENTS' CHOICE OF PICTURES IN WHICH ENERGY IS IDENTIFIED. BY GRADES, IN PERCENTAGES

Questionnaire modification

At this stage in the study, the questionnaire was revised. In the first task, students were now asked to write three associations with energy and to write sentences exemplifying the associations. In the second task, students now chose one of five alternative definitions of energy, each of which represented one of the five alternative frameworks most commonly used in the pilot study. The third task and the second part of task 5 were dropped and a second "roller coaster" task, similar to the original task 4, was added.

Questionnaire validity and reliability

Content validity of the revised questionnaire (see appendix) was confirmed by 17 judges from the fields of curriculum development, science education and physics. A total of 122 students, in grades 9-11, answered the revised questionnaire and two judges classified responses. Inter-judge agreement (excluding task 2 which was a multiple choice item) ranged from 78% to 98%. Students were retested on the same questionnaire one month later. No significant difference was found between students' responses on the two occasions for any of the questions.

Pilot study outcomes

At the grade 9 level it appears that student associations with energy are primarily with physical concepts and with phenomena, the former increasing steadily to become very dominant in grade 12, and the latter decreasing steadily. Performance on both tasks 2 and 5 suggests that the active depository (2b) is the principal explanatory framework employed at all year levels except the tenth. The depository (2a), was employed increasingly in grades 11-12, while transfer (7), the closest to a scientific framework, was prominent in grade 10 but used decreasingly in grades 11 and 12. Responses to task 4 and students' explanations of their responses indicate that about half of the grade 12 students did not use the concept of energy in dealing with the problem, and almost two thirds made no use of the concept of conservation.

THE CASE STUDY

The case study was the next step in developing a learning programme to restructure students' alternative explanatory frameworks on energy and bring them closer to accepted notions. Whereas the pilot study analysed written responses to tasks, the case study, carried out with small groups of students, was designed to encourage in-depth discussions of the ways in which students dealt with the tasks. The study proceeded in two stages. The aim of the first stage was to identify explanatory frameworks which could best be used as a basis for conceptual change. In the second stage, students were confronted with statements about situations (pictures) made on the basis of one or other of the frameworks identified in the first stage and were encouraged to identify the characteristics of these statements. It was expected that this would lead, by way of greater understanding of statements about physical situations, to a concept of energy more in keeping with a scientific explanatory framework. The case study population of 35 students comprised 16 grade 9 students with no previous instruction in physics; ten grade 10 students after one year of physics; and nine grade 11 students who had studied physics, including energy, in grade 9, and optics and waves in grade 10.

Case study - stage 1

Students first responded to the revised questionnaire on energy and were then interviewed in groups of 4 or 5 students from the same grade level. Meetings began with a discussion of questionnaire responses and continued as "interviews-about-instances" (Osborne & Gilbert, 1980). "Instances" chosen were presented in fifteen pictures (Figure 2). Interviews opened with a question like "Is there energy here?". Analysis of explanatory frameworks was based mainly on transcripts of students' descriptions ofthe pictures. One outcome of this analysis was that framework "7" was modified to become:

7a. Flow transfer - in which energy is seen as a kind of fluid transferred in some processes;

7b. An accepted scientific concept - "When two systems interact, i.e. when a process takes place, something which we call energy is transferred from one system to another". (Energy and its transformations - 1978).

It was found possible to classify 96% of students' descriptions according to the modified list of frameworks and to draw a number of conclusions about the use of alternative frameworks:

1. Frameworks "1", "2a" and "2b" are used frequently, but with decreasing frequency after the study of physics.
2. Frameworks "3", "6" and "7a" are used very rarely.
3. Frameworks "4" and "5" are used increasingly after studying physics.
4. Framework "7b", acceptable in the science community, is rarely used either before or after studying physics.

Responses to the associations task were classified according to Duit's categories (1981). Word associations were found to dominate in grade 9, but became less important with time, while as in the pilot study, energy associations with physical concepts were found to increase and to become dominant in grade 11.

Tasks 4 and 5 deal with processes involving the principle of energy conservation. As expected, student success on these tasks, and in using the concepts of energy and energy conservation, increased considerably with physics instruction. However, more than half the students used non-science ideas to explain their answers. Sixty percent of the 10th-11th graders did not use the term energy, and 80% did not use the principle of conservation.

Conclusions from stage 1 of the case study

Student responses to the tasks on association and on conservation show some success in learning, but very few students see energy within a scientifically acceptable framework such as "7b". We assume that teachers have a very limited degree of success in teaching about energy in transfer processes which take place when systems interact. In fact, students continue to hold the same alternative frameworks held before studying physics. We believe that this lack of success in teaching towards a scientifically acceptable concept of energy results in part from teaching which takes little or no account of students' alternative frameworks.

Three alternative frameworks "1", "2b" and "5", are of particular interest as they are held by many of the students in the study. The anthropocentric framework, "1", in which energy is associated with human beings, is unacceptable and very limited. It is exemplified in the following transcript of a pupil's comments on the picture of a man pushing a box up a hill (Fig. 2).

> "It's like a football player. He moves his body. He's doing an activity so there is some energy... He moves himself and he moves the box... He climbs up and uses his energy".

The student focusses attention on the man, in contrast with the same student's description of a similar situation in which the man is replaced by an electric motor.

> "There is a kinetic energy as a result of the motor pulling up the box... and also potential energy when the box is up".

Framework "2b", in which energy is seen as causing, or needed for, things to happen, and framework "5", in which energy is seen as a product of some process, are also limited frameworks representing limited views of the real world. However, each of them can be seen as a component of "7b" which is superior to both in that it maps onto larger sections of the real world and relates to a larger range of phenomena. Thus frameworks "2b" and "5", both of which are used by a majority of the case study group, are both valid albeit limited ways of thinking about energy. Assuming that they can be used as building blocks in teaching toward an acceptable view of energy, we proceeded as follows.

Case study - stage 2

Students' statements made about situations (pictures) presented in earlier discussions were recorded and for each picture, printouts were prepared of all statements categorized as representative of frameworks "2b" and "5". Small discussion groups were then presented first with the pictures and the relevant "2b" statements, and then with the same pictures and relevant framework "5" statements. In each case students were asked to examine the statements carefully and to characterize the ways in which the concept of energy had been used. Our intention in confronting students with these statements was to make provision for the identification and juxtaposition of the views of energy expressed in the "2b" and "5" statements. We present here a very limited excerpt of statements and comments.

Statements categorized as "2b"

1) Electricity in a power station needs energy to make it work.

2) The lamp runs on electricity...on electrical energy.

3) To heat the water you need some energy.

Students' comments on the "2b" statements

1) Energy makes things move...it changes from one kind to another.

2) I didn't look for it but I found only one side here...they keep repeating things like "needs energy" and "energy causes"... there's another side that's missing.

3) Energy activates things.

Statements categorized as "5"

1) Work in a power station creates electrical energy.

2) Kerosene uses oxygen as it burns and that creates energy.. that's the light and the heat.

3) When you shout you create sound energy.

Students' comments on the "5" statements

1) Everything that works here creates energy, instead of the energy making things work.

2) There isn't just energy in the air, it's made from something.

3) I think that here all sorts of actions cause energy. There it was the opposite, energy made activities.

We now wished to focus upon both the "2b" and "5" frameworks in order to move toward a more generalizable view of energy. The students were therefore asked to review their comments upon the pictures while bearing the foregoing discussions in mind. They seemed to find no difficulty in combining both aspects of energy. In one of the groups, for example, discussion about comments made on the picture of the radiator led to statements like:

1. The heating element gets energy from the electric point that comes from the power station...the electrical energy helps the element to create the heat energy.

2. I think the power station creates electricity, the electrical energy is passed on to the heater and then heat energy is created when the heating element works.

3. There's a chain of actions. If a waterfall provides energy...a special thing creates electrical energy and the electrical energy is changed to heat energy by the heating element.

In the discussions that followed, similar generalizing views on energy were expressed with respect to all of the pictured situations. We have noted that in going through this process, students were first asked to identify characteristics common to "2b" statements, then to identify characteristics common to "5" statements, and finally to discuss the pictured situations in light of these characteristics. We found that of the 35 case study students, 3 were unable to identify the common characteristics of either group of statements and 4 were able to identify these characteristics only after orientation to specific instances. For example, the following dialogue shows how the teacher helps a student who has difficulty in identifying a characteristic of "2b" statements:

Student: I think something is supplying, that causes energy...

Teacher: I don't understand.

Student: For all energies there is something that activates them, that gives the strength.

Teacher: Give me an example.

Student: In "the lighted lamp", I wrote "activated by electrical energy from a source like the electric company".

Teacher: And that means?

Student: Ah! Energy activates the lamp! That's the characteristic.

Twenty eight students found no difficulty in identifying the characteristics of the two groups of statements, and 17 were able both to identify the characteristics of each group and to describe relationships between the two groups of statements. This is exemplified by the following student statements:

1) The common thing here is talk about creating energy...but energy isn't made, it's just in another form. In a power station that's worked by a waterfall that the water changes into electricity, the electricity is made by the force of the water, but the force is just another kind of energy.

2) I want to connect it with the things we did before. First of all the energy makes things work. We agreed on that, right? Then, when it makes something work, energy is made... it doesn't matter what kind. Then as soon as energy makes something work... some kind of energy is created.

3) The idea is that energy is the result of something. It doesn't just cause something, it's made by some activity or other.

In our view, understanding of the relationships between the two groups of statements is the logical step which makes it possible to combine frameworks '2b' and '5' to form framework '7b'. This suggests that the development of student facility in identifying approaches to the energy concept, and confrontation with alternative approaches, does provide a way of narrowing the gap between students' alternative conceptual frameworks and a framework acceptable to the scientific community.

Classroom teaching about energy does not normally make provision for the scrutiny of alternative explanatory frameworks. Nor does it normally take into account the explanatory frameworks held by students prior to the study of energy related topics. It usually proceeds by means of a variety of approaches in which students are provided with experiences related to instances of energy in various forms, transformation from one form to another, energy calculations, solving of energy related problems, and laboratory experiments confirming the principle of conservation. This is borne out by a scrutiny of syllabi, guidelines and practices in school science such as that carried out in almost thirty countries around the world within the framework of the Second International Science Study (SISS) (Finegold and Raphael, 1988). Some of the curricular case studies carried out as part of the SISS (Finegold and MacKeracher, 1985), point to a need for change in the concept of energy as taught in schools. The findings reported here suggest that the teaching method explored, used with small groups or adapted to the needs of the standard classroom, can enrich schooling by making provision for learning about energy in a scientifically acceptable manner.

ACKNOWLEDGEMENT

We thank Gilbert and Ogborn for the use of some of the pictures used and Duit for his questionnaire and category system.

APPENDIX

QUESTIONNAIRE ON ENERGY (Abridged)

1. What are the first three words you think of when you hear the word "energy"? Write three sentences, each including one of these words and the word "energy".

2. Here are five sentences about energy. Mark the one closest to your own definition or description of energy.

   A. Energy is a property deposited in some objects, e.g., "There is electric energy in a battery".

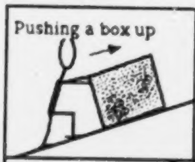
   B. Energy causes some objects to carry out some activities, e.g., "Solar energy heats the water in the boiler".

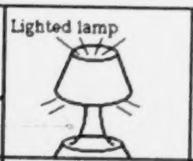
   C. Energy is something transferred from one object to another and appears in different forms, e.g."A TV set transforms electrical energy into light and sound energy".

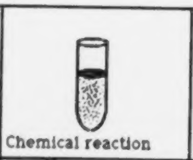
   D. Energy is an activity, e.g., "A fire burning, a phone ringing, people running".

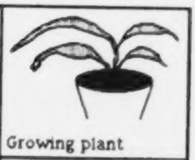
   E. Energy is created by some activities, e.g., "A turning wheel drives a turbine that creates electrical energy".

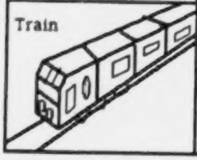
3. Examine these pictures and choose three involving energy which you understand best. Explain each choice in 1 or 2 sentences using the word 'energy'.

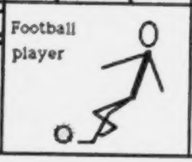

Pushing a box up

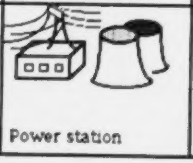

Lighted lamp

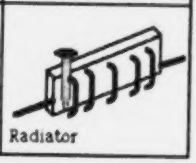

Chemical reaction


Growing plant

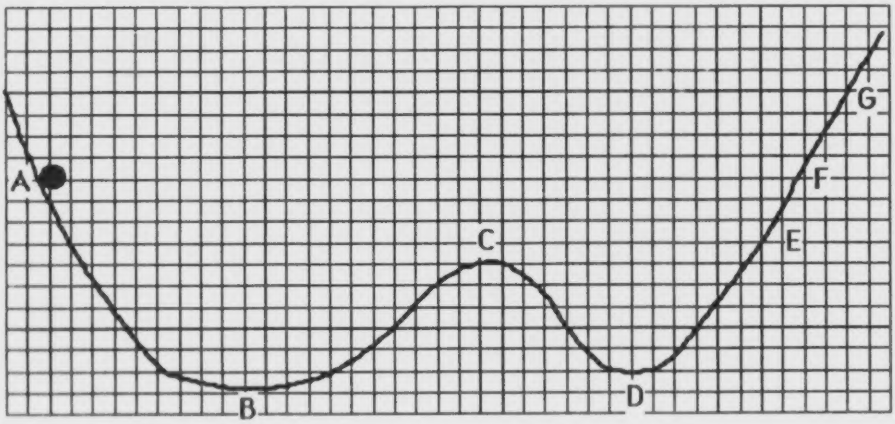

Train


Football player

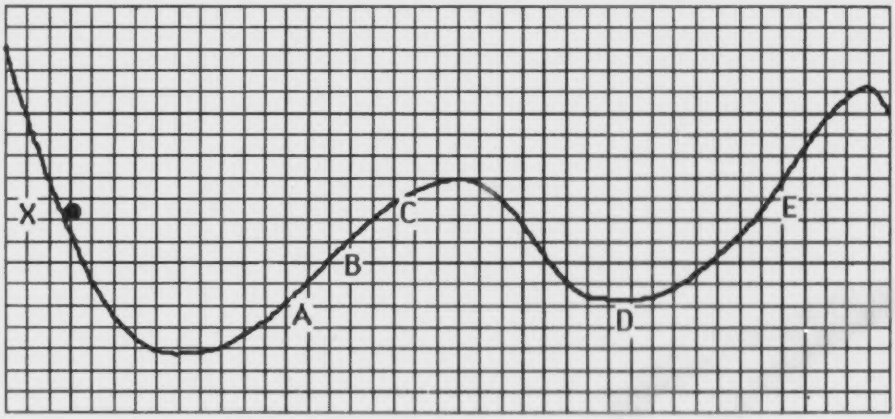

Power station


Radiator

4. A ball is released at "A" on the path shown and rolls freely. Mark the spot the ball will reach before it begins to roll back. Explain your answer.



5. A ball is released at "X" on the path shown. Mark the furthest spot you think the ball will reach on the path and explain your answer.



REFERENCES

BLISS, J. & OGBORN, J. (1985). Children's choices of uses of energy. European Journal of Science Education, 7, 195-202.

DUIT, R. (1981). Students' notions about the energy concept- before and after physics instruction. in: Jung, W., Pfundt, H., and Rhoneck, C. (Editors) Proceedings of international workshop "Problems concerning students' representations of physics and chemistry knowledge" 268-319. Ludwigsburg Pedagogische Hochschule.

DUIT, R. (1984). Learning the energy concept in school - Empirical results from Philippines and W. Germany. Physics Ed. 19, 59-66.

Energy and its Transformations (1978). Curriculum Development Centre, Ministry of Education, Israel.

FINEGOLD, M. & MACKERACHER, D. (1985) The Canadian Science Curriculum, chapter in: Connelly, F.M., Crocker, R.K. & Kass, H. Science Education in Canada: Policies, Practices, and Perceptions Volume 1 150-172, Toronto, Ontario, OISE Press.

FINEGOLD, M. & RAPHAEL, D. (1988). Physics in Canadian secondary schools: intentions, perceptions, and achievement. Journal of Research in Science Teaching 25 No. 4 293-315.

GILBERT, J.K., & POPE, M.L. (1986). Small group discussions about conceptions in science: A case study. Research in Science and Technological Education 4, 61-76.

OSBORNE, R.J. & GILBERT,J.K. (1980). A method for investigating concept understanding in science. European Journal of Science Education, 2, 311-321.

WATTS, D.M. (1983). Some alternative views of energy. Physics Education, 18, 213-217.

Research In Science Education, 1989, 19, 112 - 122

AN ACCOUNT OF ACTION RESEARCH INVESTIGATING TEACHER CHANGE

Lingbiao Gao, Hewa Adcock, Malcolm Carr, Anne Hume,
David Nicholson, Janet Silvester and Daryl Smith.

PROJECT RATIONALE

The LISP (Learning in Science Project) research carried out in SERU (Science Education Research Unit), University of Waikato, Hamilton, New Zealand in the past decade, has suggested a change towards a more student-centred and interactive science education, Osborne & Freyberg (1985); Osborne & Wittrock (1985); Biddulph & Osborne (1984); Cosgrove, Osborne & Tasker (1982). This implies a major change to teachers' current practice and gives rise to the questions how teachers can be encouraged to realise the need for those changes, and what strategies could be used to assist them. To address these problems, it is important to understand the process of teacher change, to find out the factors which affect change and to design suitable programmes to promote it. These are the focuses of SERU's current project LISP (Teaching), Claxton & Carr (1987). These are also the focuses of this mini project.

In order to make this project more practical and benefit both the teachers' teaching and the research, we used the so called 'action research' method (Elliott, 1978). A working group including four high school science teachers was organised. We tried to promote and assist their changes and to observe the process at the same time. However, instead of telling teachers what they needed to change and giving them the direction of change, we tried to create a suitable atmosphere so that teachers could challenge themselves, find out where they were and where they wanted to go, solve the difficulties and problems they met as they changed.

Using this method, the emphasis of our research was to create suitable conditions using videotaping techniques and organising workshops for teachers to interact. The videoed teaching sequences were taken during ordinary classroom sessions. We let the teachers themselves choose the topics and the teaching techniques. After each videotaping, the teachers were asked to observe and analyse their own teaching. They came together in a workshop when everyone showed his/her video and explained his/her teaching strategy to the others. They discussed any changes they had experienced in the past or in their videoed teaching sequence, shared ideas about difficulties associated with change, and procedures which might assist change. During the whole project we avoided any kind of evaluation or criticism of any teacher or any style of teaching, so the teachers felt relaxed and comfortable throughout.

THE PARTICIPANTS

The teachers in the working group played a very important role in this project. They had to be able to contribute actively, independently and honestly. We also hoped that they could bring a variety of teaching styles, techniques and ideas into the group interaction. To organise this working group, Gao observed 23 periods of high school science in 5 schools in Hamilton and talked with 9 teachers in March, 1988. From the teachers involved in the field observation we sought four teachers of different age, sex, educational and cultural background, teaching experience, belief and style of teaching. Then Gao interviewed them informally to discover their past experience, attitudes about teaching and learning, and to determine their commitment to the project. The four teachers selected for the working group were:

(A) Mrs. Hewa Adcock
Female, New Zealand born, Maori, Age: 25-30 ;
BSc. (Chem. & Math.) Auckland, N.Z.
5 years teaching experience ;
Worked in a girls' high school during the research.

(H) Mrs. Anne Hume
Female, British born, Age: 35-40 ;
BSc. (Geo.) Auckland, N.Z. ; Dip.Ed.St. Waikato, N.Z.;
13 years teaching experience ;
Worked in a girls' high school during the research.

(N) Mr. David Nicholson
Male, came to N.Z. from England in 1980, Age: 40-45 ;
BSc. (Mech. Eng.) Edinburgh, Scot. ;
6 years teaching experience ;
Worked in a co-educational high school during the research.

(S) Mr. Daryl Smith
Male, New Zealand born, Age: 35-40 ;
BSc. (Phys.) Otago, N.Z. ;
14 years teaching experience ;
Worked in a boys' high school during the research.

THE RESEARCH PROCEDURE

Time	Research Programme
March 1988	Field observation and proposal making
April 1988	Interviews, working group organisation
June 1988	Review of the research proposal
July 1988	First set of videotaping
August 1988	First workshop & Review of the first round of the research
September 1988	Second set of videotaping
October 1988	Second workshop & Review of the second round of the research & Questionnaire survey
November 1988	Research report

CHANGES EXPERIENCED BY TEACHERS IN THE WORKING GROUP

From the conversations of the teachers in the working group (Research Information 2, 4, 5) and their videotaped teaching procedures (Research Information 3), we can describe their experiences of change as follows:

1. Changing Experiences of Mrs. Hewa Adcock

Mrs. Adcock had five years' teaching experience and had been involved in the LISP (Energy) project. She enjoyed teaching and trying new teaching techniques. She felt that she had undergone many changes since she started her teaching career and was still in the process of change. When talking about her ideas of school science and teaching strategies during the first interview, she said that she still felt insecure.

In her first videotaped lesson she tried a new method of teaching her students problem solving skills. She felt unsure and a little dissatisfied with some of the techniques she had used, because at the beginning of the discussion period the students were not very enthusiastic about discussing the questions which she thought were important. There was no interaction between students and no questions came from them.

After watching other teachers' videos and discussing with them, she realised her problem was that she was still the centre of the class. In her second videotaped lesson, Mrs. Adcock kept on trying new teaching techniques. The normal way of teaching this lesson, which required a lot of background knowledge, was to lecture from the front and give students written exercises. She changed it into a series of mini problem solving and 'brainstorming' sessions. She paid more attention to encouraging students to present their ideas and was more relaxed about students doing their own learning.

Mrs. Adcock really believed in teaching and learning with a more student centred and interactive model. She was keen on absorbing new techniques which could put this philosophy into practice. After each video discussion she had new ideas and tried them in her teaching. She considered that the difficulties and worries encountered in change could arise mainly from the teacher him/herself, the students, and a lack of communication between teachers.

2. Changing Experience of Mrs. Anne Hume

Mrs. Hume became a high school teacher thirteen years ago and is now the head of science at Hamilton Girls' High School. She changed almost the whole style of her teaching in the past few years. She gradually felt very bored and nearly gave up teaching after years of a teaching career which had seemed to be so bright and successful. However, after being influenced by SERU and Dr. Osborne and inservice courses, she gradually changed her ideas about teaching and learning and used every opportunity to put them into practice. By the beginning of this year she started to develop her own pedagogy and felt confident with it. She considered that at that time her change was in a stage of "fine - tuning".

In her three videotaped lessons, she tried a variety of teaching techniques developed in recent years such as 'brainstorming', problem solving and resource based learning. In all these techniques she concentrated on making the students more responsible for their own learning and encouraged them to think scientifically.

She felt satisfied with the techniques she had used and shared her experiences with others. By watching other teachers' videos and discussing with them, she got their perspectives and compared her experiences with theirs. She identified and elaborated her ideas. These clarified her ideas and reinforced her confidence. She also recognised some shortcomings in her teaching, eg. her classes were sometimes too language-oriented, so she modified her techniques. When other teachers found something difficult when trying new techniques she was very happy to share her experiences. When they were not sure with some ideas, she liked to offer suggestions. She identified change in the other teachers and tried to find an acceptable way to promote change in her department which would keep the support of her colleagues.

3. Changing Experience of Mr. David Nicholson

Mr. Nicholson was an engineer before becoming a teacher eight years ago. He thought that he was still confused about the policy of school science and was dissatisfied with some aspects of his teaching methods and unhappy with some of the results of his teaching. He was influenced by the LISP materials and wanted to change.

In his first video teaching sessions he used the 'brainstorm' technique and let students decide what they wanted to learn about that topic. Each group of students in his class chose an experiment according to the things which interested them. They did the experiment and then demonstrated them to the whole class. He found that most of the students were very involved in their learning and during those periods he and his students developed a good relationship. He felt happy about that but still felt uneasy because the class seemed less controlled and one or two students were not involved in the activity. He was not sure what 'interactive teaching' really meant and what kinds of results he could expect if he kept teaching that way. He wondered if he should go back a little bit to a method which would give him confidence.

In his next videotaped teaching session, he taught in a more structured way. He chose and outlined the experiments for the students but let them work out the details. He felt frustrated about returning to a situation of more control and realised he should maintain his original direction of change. After viewing this second video and discussing it with other teachers in the workshop, he found that he had in fact changed several aspects of his teaching. He felt comfortable with this and thought that he could develop a variety of teaching techniques.

4. Changing Experience of Mr. Daryl Smith

At the beginning of this project, Mr. Smith regarded himself as a traditional type of teacher. His first videotaped teaching session was quite structured using the lecturing, demonstrating and questioning techniques. Students were busy taking notes, answering questions, observing demonstrations and doing experiments following his instruction. He was unsure about the way he had taught and wanted to find a new way of teaching. He was dissatisfied with his teaching results on one hand yet had doubts about the interactive approach to teaching on the other.

In the first workshop he discussed his worries with other teachers, found out their experiences and compared their new ideas with his own. He finally decided to tried some new techniques.

In his second videotaped teaching session Mr. Smith made a big change. He used some techniques which he had never used before, such as 'brainstorming', resource learning, etc.. He also let the students decide what they wanted to learn. He supported the students when they needed help but did not dictate what they had to do. He found that the students were much more involved and active than usual and they achieved a great deal. He didn't need to worry about class control and felt more relaxed because the pressure on him had been much less than usual. Both the students and he were satisfied with this new style of teaching. He thought he had a better feeling about science and really taught the skills and methods of science this time. He said he felt like a real science teacher rather than a mathematics teacher as he used to be.

As it was the first time he had tried these new techniques, he still found some things difficult to handle, such as not giving a direct answer to students' questions and how to measure students' achievement. He also found further problems such as the students' need for a proper framework and their lack of practical skills. He still worried about content, school policy and the examination set for the senior students, but he was quite confident and intended to proceed with this new style.

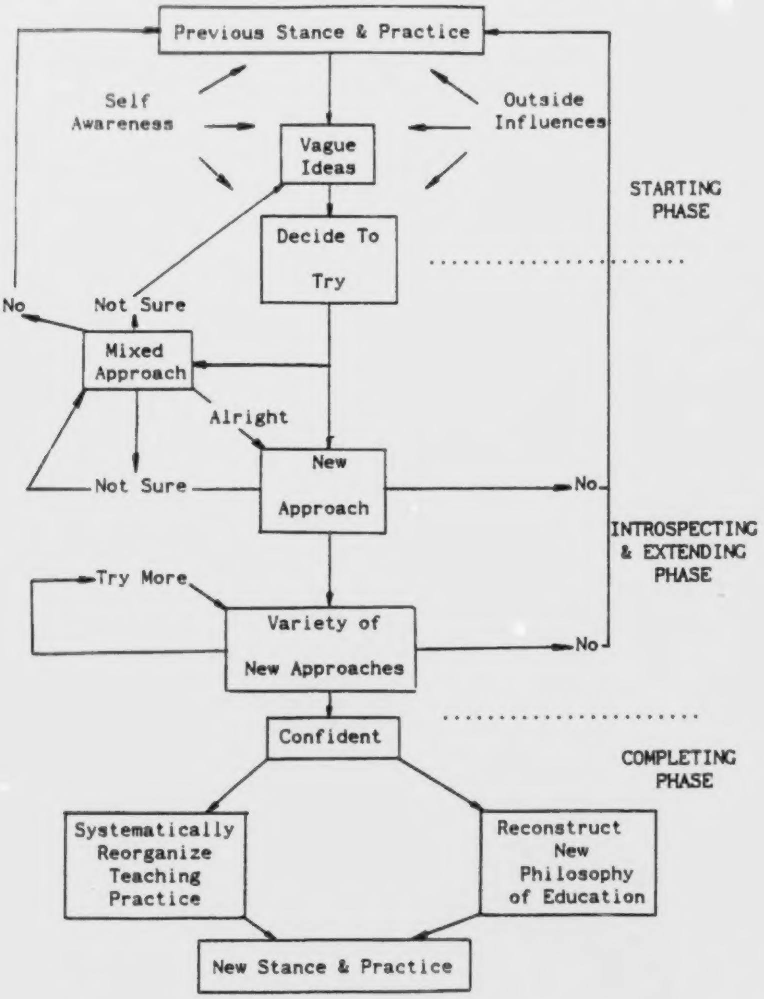
A MODEL OF THE CHANGING PROCESS

Claxton and Carr (1987) pointed out that it would be impossible to specify any precise sequence of changes that teachers go through in the course of reorientating and reintegrating their educational stance and practice, however a number of decision points in a possible scenario could be suggested. They used a series of words to describe the process of change:

> entrenchment - opposition - possibility - dabbling - clarification - introspection - planning - reaction - deflation - projection - reaffirmation - extension - consideration - permeation.

The experiences of the teachers involved in this project support their opinion and enable us to describe these decision points in a diagram to produce a clearer picture of change.

Diagram 1: Process of Change


Previous Stance & Practice
Self Awareness
Outside Influences
Vague Ideas
Decide To Try
STARTING PHASE
No
Not Sure
Mixed Approach
Alright
Not Sure
New Approach
No
INTROSPECTING & EXTENDING PHASE
Try More
Variety of New Approaches
No
Confident
COMPLETING PHASE
Systematically Reorganize Teaching Practice
Reconstruct New Philosophy of Education
New Stance & Practice

Experiences of the teachers in the working group indicated that change could not happen unless they felt dissatisfied with their previous stances and practices of teaching. However, self-dissatisfaction only, was not enough to push them to reorientate their style of teaching. External influences such as talking with other people, reading a book, discussing with peer groups, and other internal influences such as an open mind to change were also necessary. At this phase, the teachers might have vague ideas about where and how they should go. They might be dissatisfied, and have doubts and worries about the old and new ideas and teaching practices. The teachers might hesitate in this stage for a long time if the impacts on them were not strong enough. But as these influences gradually became stronger, the teachers might recognise and accept the need to change, and might decide to 'have a go'. We named this first phase of change as the *Starting* Phase.

Teachers then put the new ideas and techniques into practice. They might like to follow the new approach exactly. But, in most cases, because their ideas might be still vague and unclear, the new and old philosophies and techniques were all mixed together. Because they still did not totally believe in the new approach, what they actually did might be some sort of mixed approach.

With feedback from the teachers' own feelings, the students' feelings and achievements, other teachers and the principal, and even people outside the school, the teachers could react in very different ways.

With negative feedback, teachers could say 'no' and decide to go back to their previous position. They might stay there or try again later if they received further impacts.

With neutral or confusing feedback, teachers could decide to wait until their ideas clarify. In this case they might go back to the starting phase with vague ideas. They could decide to repeat and gradually improve their mixed approach until they received positive feedback then decide to continue. In some cases teachers revert from a new approach to a mixed approach.

If feedback was positive, most teachers would continue to try the new approach, using it in different topics and different situations until they could feel confident about using it. Then they would extend their interests and try more new approaches. Each time teachers tried something new, they could get negative feedback and return to their previous positions, or they could repeat the new routine until the new ideas were eventually accepted.

As their practice continued, their new ideas would become clearer, and the teachers would gradually believe in them, developing a variety of new techniques to use them. Finally they would become convinced about the new style of teaching and philosophy behind it. This was the most important phase of change for the school teachers. It might last a long time and have no definite end-point. We named it the *Introspecting and Extending* phase.

In this situation, teachers might consider that they had already finished their change and never think about progressing any further. In fact, many teachers might stop at this position. However, some of the teachers might keep on progressing. They might reorganise their teaching practices, and at the same time reconstruct their philosophy of teaching, learning and education in general. This might include rewriting the school scheme to take account of the new views, changing their methods of assessing students, being involved in curriculum reform, etc.. This much deeper and more difficult level of change we named the *Completing* phase. After this phase, those teachers became really powerful and creative professionals.

SUGGESTIONS FOR ASSISTING TEACHERS TO CHANGE

What do the experiences of teachers in the working group and the model of change imply for facilitating change?

1. Change is promoted when teachers' self awareness is encouraged. To change a style of teaching depends more on the teachers themselves than on any other person. They cannot be made to change. What we can do is create a supportive environment which enables them to think about their own teaching, examine the ideas of other teachers, researchers and educators, compare their teaching with these others and then allow them to make the decision to change and the way to go about it, by themselves.
2. When teachers undergo change, they need support in both psychological and practical ways. Psychological support includes encouragement from society, school, students and other teachers. They also need other teachers to share their experiences, reinforce their ideas and increase their confidence. Physical support includes practical help to overcome difficulties which they meet in changing. These could be teaching material, books explaining the new teaching ideas, or demonstrations of the new way of teaching.

   In this project, we tried to create an environment enabling teachers
   - to review their own ideas and practice of teaching,
   - to hear comments from other teachers about their teaching,

- to see how other teachers teach and know what they think.
- to have contact with recent developments in science education research,
- to be free in teaching, observing, analysing, listening, communicating and making decisions.

We attempted to make everyone feel as comfortable, relaxed and unthreatened as possible so they were able to consider their own and other teachers' teaching and the latest outcomes of science education research.

The techniques used to create such an environment were videotaping and workshops. These enabled teachers to see what they looked like in the classroom, to get the students' responses to their teaching, and to question whether it was the sort of teaching they wished to do. They also enabled everyone to see other teachers' teaching in detail and exchange ideas and share experiences. These conditions helped everyone find out what they needed to change and helped them make that change.

Teachers in the working group all gave positive comments about these techniques.

Mrs. Adcock:

> *These discussions were valuable and I gained a lot from them. I felt comfortable because all of the other teachers were willing to listen and share ideas, opinions and thoughts honestly. All criticisms were constructive. It made me realise how important it was to communicate with other teachers and that this was an important activity which stimulates new ideas and thus change in teaching methods.*

Mrs. Hume:

> *I think the video technique was the most helpful. You were able to stand back as an observer and see pupils/teacher responses to one another - not just in the immediate area but in other parts of the room. It gave a general overview of the lesson and class happenings - it was very easy to pick up the sequence of the lesson.*
>
> *I would see the video as a very useful technique for promoting change, particularly as a means by which practising teachers could see new styles and strategies in action.*

Mr. Nicholson:

> *I found the methods used very interesting and helpful. The comment and ideas of the other group members were particularly useful. I did not feel I was being assessed or criticized at any time during the project.*

Mr. Smith:

> *The actual video. Seeing myself as others see me, and being aware that I do something well, while other aspects needs attention.*
>
> Sharing of views in discussion with other professionals was a big bonus

(pp.3-7, Research Information 6, QUESTIONNAIRE SURVEY, November 1988)

3. Teachers are not totally free to decide what and how to teach. They are restricted by the curriculum, examination system, school policy and many other factors such as the attitude of parents, etc... If we want to have more impact on changing teachers' teaching, we have to do more work re-organising the school science curriculum according to the new philosophy. We have to find a better method to assess students' achievement and help the school and community change their attitudes. It is difficult for one person or a small number of teachers to achieve this. It needs support from a higher level, for example, the Department of Education, to organise activities, such as workshops for principals, inspectors and advisers. It needs further research in these areas to identify and find solutions to the problem of teachers' changing.

REFERENCES

BIDDULPH, F. & OSBORNE, R. (1984) Making Sense of Our World, Science Education Research Unit, University of Waikato, Hamilton, New Zealand.

CLAXTON, G. & CARR, M. (1987) Understanding Change: The Personal Perspective, Working Paper No. 401, Science Education Research Unit, University of Waikato, Hamilton, New Zealand.

COSGROVE, M. OSBORNE, R. & TASKER, C. (1987) Towards Generative Learning, Working Paper No. 205, Science Education Research Unit, University of Waikato, Hamilton New Zealand.

ELLIOTT, J. (1978) What Is Action Research In Schools, Journal of Curriculum Studies, 10(4), 355-357.

OSBORNE, R.J., FREYBERG, P. (1985) Learning in Science: the Implication of Children's Science, Heinemann (N.Z.)

OSBORNE, R.J. & WITTROCK, M. (1985) The Generative Learning Model and Its Implications for Science Education. Studies in Science Education, 12, 59-87.

Research in Science Education, 1989, 19, 123 - 132.

DEVELOPMENT OF AN INSTRUMENT FOR ASSESSING THE PSYCHOSOCIAL ENVIRONMENT OF SCIENCE LABORATORY CLASSES

Geoffrey J Giddings and Barry J Fraser

This paper describes the development of a new instrument to assess perceptions of psychosocial environment in science laboratory classrooms, and reports comprehensive validation information for several samples of students and teachers. The work described here is distinctive in that it extends research traditions in non-laboratory settings to science laboratory classes. Before describing the development and validation of the new instrument, important background information about science laboratory settings and about analogous work in non-laboratory classroom environments is briefly reviewed.

BACKGROUND

Laboratory teaching is one of the unique features of education in the sciences, but we are beginning to see a questioning of whether the great expense of maintaining and staffing laboratories is really justified (Hofstein & Lunetta, 1982) and whether many of the aims of laboratory teaching could not be pursued more effectively and at less cost in non-laboratory settings (Pickering, 1980). Furthermore, students' reactions to practical work often confirm the views of critics. It is quite common to hear students say that laboratories are boring and that they go through the motions of experimentation without stimulation and often without any clear purpose. But, because research has not been comprehensive, we simply do not know enough about the effects of laboratory instruction upon student learning and attitudes. Consequently, it is timely to initiate a new line of research which could help us to obtain feedback about students' views of laboratory settings and investigate the impact of laboratory classes on students.

Over the previous two decades, considerable interest has been shown internationally in the conceptualization, measurement and investigation of perceptions of psychosocial characteristics of the learning environment of classrooms at the primary, secondary and tertiary levels (Fraser, 1986a, 1986b; 1989; Fraser & Walberg, in press). A feature of most of the classroom environment instruments listed above is that they have four distinct forms which measure (a) student perceptions of actual classroom environment, (b) student perceptions of preferred classroom environment, (c) teacher perceptions of actual classroom environment, and (d) teacher perceptions of preferred classroom environment. The preferred forms are concerned with goals and value orientations and measure perceptions of the classroom environment ideally liked or preferred.

Classroom environment instruments have been used as sources of predictor and criterion variables in a variety of research studies conducted in primary and secondary schools. Use of student perceptions of actual classroom environment as predictor variables in several different countries has established consistent relationships between the nature of the classroom environment and various student cognitive and affective outcomes (see Haertel, Walberg & Haertel, 1981). For example, Fraser and Fisher's (1982) study involving 116 Australian science classes established sizable associations between several inquiry skills and science-related attitudes and classroom environment dimensions measured by the Classroom Environment Scale and the Individualised Classroom Environment Questionnaire.

Studies involving use of the actual form of classroom environment scales as criterion variables have revealed that classroom psychosocial climate varies between different types of schools (Trickett, 1978), and between coeducational and single-sex schools (Trickett, Trickett, Castro & Schaffner, 1982). Both researchers and teachers have found it useful to employ classroom climate dimensions as process criteria of effectiveness in curriculum evaluation because they have differentiated revealingly between alternative curricula when student outcome measures have shown little sensitivity (Fraser, 1981). Moos (1979) in the USA and Fraser (1982) in Australia compared students' and teachers' perceptions and found that, first, both students and teachers preferred a more positive classroom environment than they perceived as being actually present and, second, teachers tended to perceive the classroom environment more positively than did their students in the same classrooms. In promising small-scale practical applications, teachers have used assessments of their students' perceptions of their actual and preferred classroom environment as a basis for identification and discussion of actual-preferred discrepancies, followed by a systematic attempt to improve classrooms (Fraser & Fisher, 1986).

INITIAL DEVELOPMENT OF THE SLEI

The initial development of the Science Laboratory Environment Inventory was guided by the following five criteria:

1. Consistency with the Literature on Laboratory Teaching. A review of the literature was undertaken for the purpose of identifying dimensions that are important in the unique environment of the science laboratory class (Giddings & Hofstein, 1980; Lunetta, Hofstein & Giddings, 1981; Hofstein & Lunetta, 1982).

2. Consistency with Instruments for Non-Laboratory Settings. Guidance in identifying dimensions was obtained by examining all scales contained in existing instruments for non-laboratory settings.

3. Coverage of Moos' General Categories. Dimensions chosen provided coverage of the three general categories of dimensions identified by Moos (1974) for conceptualizing all human environments. These three general categories are Relationship Dimensions (the nature and intensity of personal relationships), Personal Development Dimensions (basic directions along which personal growth and self-enhancement tend to occur) and System Maintenance and System Change Dimensions (extent to which the environment is orderly, clear in expectation, maintains control and is responsive to change). Because Moos claims that, at minimum, Relationship Dimensions, Personal Development Dimensions and System Maintenance and System Change Dimensions must be assessed to provide an adequate and reasonably complete picture of any environment, dimensions for the SLEI were chosen to include scales in each of Moos' three general categories.

4. Salience to Tertiary Teachers and Students. By interviewing a number of science teachers and students at the upper secondary and tertiary levels and asking them to comment on draft versions of sets of items, an attempt was made to ensure that the SLEI's dimensions and individual items were considered salient by teachers and students.

5. Economy. In order to achieve economy in terms of the time needed for answering and scoring, the SLEI was designed to have a relatively small number of reliable scales, each containing a fairly small number of items.

It was found that the above criteria could be satisfied with an instrument containing the following eight scales: Teacher Supportiveness, Involvement, Student Cohesiveness, Open-Endedness, Integration, Organization, Rule Clarity and Material Environment. By writing new items and rewriting existing ones, scales selected from inventories for non-laboratory settings were redefined and modified to make them well-suited to laboratory classes. The set of items passed through several successive revisions based on reactions solicited from colleagues with expertise in questionnaire construction and science teaching at the secondary and tertiary levels. Careful attention was paid to making each item suitable for measuring both actual and preferred classroom environment.

The resulting preliminary version of the SLEI contained nine items per scale. Both the actual and preferred forms were field tested with a sample of teachers and students from six countries, namely, Australia, the USA, Canada, England, Israel and Nigeria. For the purposes of this paper, illustrative validation data are provided for the Australian and the USA samples only.

Data are being subjected to item analysis in order to identify items whose removal would enhance each scale's internal consistency (the extent to which items in the same scale measure the same dimensions) and discriminant validity (the extent to which a scale measures a unique dimension not covered by the other scales in the instrument). In particular, an attempt is being made to improve scale internal consistency by removing items with low item-remainder correlations (i.e., correlations between a certain item and the rest of the scale excluding that item), and to improve discriminant validity by removing any item whose correlation with its a priori assigned scale was lower than its correlation with any of the other seven scales in the SLEI. These procedures are being applied to the data from each of the six countries as they become available in order to evolve a refined version with somewhat less than nine items per scale.

DESCRIPTION OF SLEI

The unrefined version of the SLEI contains 72 items altogether, with an equal number of items belonging to each of the eight scales. Each item is responded to on a five-point scale with the alternatives of Almost Never, Seldom, Sometimes, Often and Very Often. The scoring direction is reversed for approximately half of the items. Table 1 clarifies the meaning of each SLEI scale (which has a common-sense meaning) by providing its classification according to Moos' scheme, a scale description and a sample item. The items listed in Table 1 are from the actual form of the SLEI, but the wording of the preferred form is almost identical except for the use of words such as

TABLE 1: Descriptive Information for Each Scale in the Science Laboratory Environment Inventory (SLEI)

Scale Name	Moos Category	Description	Sample Item
Teacher Supportiveness	R	Extent to which the teacher/instructor is helpful and shows concern for all students.	The teacher is concerned about students' safety during laboratory sessions. (+)
Involvement	R	Extent to which students participate actively and attentively in laboratory activities and discussions.	During laboratory group work students leave it to their partners to do all the work. (-)
Student Cohesiveness	R	Extent to which students know, help and are supportive of one another.	Students in this laboratory class get along well as a group. (-)
Open-Endedness	P	Extent to which the laboratory activities emphasize an open-ended, divergent, individualized approach to experimentation.	We know the results that we are supposed to get before we commence a laboratory activity. (-)
Integration	P	Extent to which the laboratory activities are integrated with non-laboratory and theory classes.	We use the theory from our regular science class sessions during laboratory activities. (+)
Organization	S	Extent to which the laboratory activities are clearly defined and well organized.	There is confusion during laboratory classes. (-)
Rule Clarity	S	Extent to which behaviour in the laboratory is guided by formal rules.	There is a recognized way of doing things safely in this laboratory. (+)
Material Environment	S	Extent to which the laboratory equipment and materials are adequate.	The laboratory is too crowded when we are doing experiments. (-)

R: Relationship Dimension; P: Personal Development Dimension; S: System Maintenance and System Change Dimension

Items designed (+) are scored 1, 2, 3, 4, and 5, respectively for the responses Almost Never, Seldom, Sometimes, Often and Very Often. Items designated (-) are scored in the reverse manner. Omitted or invalid responses are scored 3.

"would". For example, the item "The teacher goes out of his/her way to help students" in the actual form is reworded in the preferred form to read "The teacher would go out of his/her way to help students".

VALIDATION OF THE SLEI

Samples

Some preliminary validation data for the actual and preferred forms of the SLEI are reported here for the unrefined version of the scales for some of the data collected in the USA and Australia. The three different samples consisted of 902 American students in senior high school classes, 583 American students in university classes, and 293 Australian students in senior high school classes. For each sample, a spread of science subjects (chemistry, physics, biology) was involved.

Internal Consistency Reliability

The first index of validity reported is scale reliability (see Table 2). Estimates of the internal consistency of the actual and preferred forms of each SLEI scale were calculated using Cronbach's alpha coefficient. Data are reported separately for actual and preferred forms and for the three different samples using the individual as the unit of analysis. Table 2 shows that, for the sample of Australian school students, the values obtained for the alpha coefficient ranged from 0.56 to 0.85 for the actual form and from 0.55 to 0.71 for the preferred form. Data for the other samples in Table 2 (American school students and American university students) compare favourably with these values. These data together suggest that each SLEI scale has acceptable internal consistency, especially for scales containing only nine items each, in both its actual and preferred forms, for both Australian and American students. When all data from the six countries are to hand, it is envisaged that a small number of items will be eliminated from each SLEI scale in order to achieve some improvements in the values of the scale reliability shown in Table 2.

TABLE 2: Cronbach Alpha Reliability Coefficients for Actual and Preferred Forms of SLEI for Three Different Samples

		Alpha Reliability		
Scale	Form	USA school students (N=902)	USA university students (N=583)	Australian school students (N=293)
Teacher Supportiveness	Actual	0.83	0.84	0.77
	Pref.	0.78	0.78	0.61
Involvement	Actual	0.66	0.50	0.66
	Pref.	0.61	0.65	0.55
Student Cohesiveness	Actual	0.82	0.75	0.81
	Pref.	0.77	0.75	0.66
Open-Endedness	Actual	0.69	0.43	0.56
	Pref.	0.63	0.56	0.57
Integration	Actual	0.83	0.88	0.85
	Pref.	0.80	0.81	0.71
Organization	Actual	0.82	0.79	0.82
	Pref.	0.78	0.80	0.70
Rule Clarity	Actual	0.79	0.75	0.70
	Pref.	0.74	0.72	0.63
Material Environment	Actual	0.76	0.74	0.80
	Pref.	0.77	0.76	0.70

Discriminant Validity

Data about discriminant validity were generated using the mean correlation of a scale with the other seven scales as a convenient index for the same three samples. For the sample of 293 Australian school students, discriminant validity indices ranged from 0.24 to 0.49 for the actual form. Comparable values were obtained for the other two samples. Although only arbitrary criteria exist, generally these values can be regarded as small enough to suggest that each SLEI scale has adequate discriminant validity for use in its actual and preferred forms with either Australian and American students. It appears that the SLEI measures distinct although somewhat overlapping aspects of classroom environment; but, the conceptual distinctions among scales are important enough to retain the eight dimensions within the instrument.

Ability to Differentiate Between Classrooms

A third desirable characteristic of the student actual form of any classroom environment instrument is that it is capable of differentiating between the perceptions of students in different classrooms. That is, students within the same class should perceive it relatively similarly, while mean within-class perceptions should vary from classroom to classroom. This characteristic was explored for each scale of the student actual form of the SLEI for each of the three samples described previously. This involved performing for each scale a one-way ANOVA, with class membership as the main effect and using the individual as the unit of analysis. The results of the analyses indicated that each scale differentiated significantly ($p<0.001$) between classrooms for each sample of students.

CONCLUSION

This paper attempts to stimulate and facilitate future research and practical applications involving the psychosocial environment of science laboratory classrooms by describing the development of a new instrument, the Science Laboratory Environment Inventory (SLEI), which assesses eight dimensions of the actual and preferred environment of science laboratory classes at the upper secondary school and higher education levels. Comprehensive validation information reported herein tentatively attests to the internal consistency reliability and discriminant validity of the actual and preferred forms of the SLEI for use in Australian or American classrooms. As well, further analyses supported the ability of the actual form of the SLEI to differentiate between the perceptions of students in different classrooms. It is hoped that science teachers and other researchers will make use of the SLEI to pursue several research and practical applications analogous to those completed successfully in prior work in non-laboratory classrooms.

REFERENCES

FRASER, B.J. (1981). Learning environment in curriculum evaluation: A review. Evaluation in Education series. Oxford, Pergamon.

FRASER, B.J. (1982). Differences between student and teacher perceptions of actual and preferred classroom learning environment. Educational Evaluation and Policy Analysis, 4, 511-519.

FRASER, B.J. (1986a). Classroom environment. London, Croom Helm.

FRASER, B.J. (1986b). Two decades of research on perceptions of classroom environment. In B.J. Fraser (Ed.), The study of learning environments. Salem, Oregon, Assessment Research.

FRASER, B. (1989). Twenty years on classroom environment work: Progress and prospect. Journal of Curriculum Studies. (in press)

FRASER, B.J.& FISHER, D.L. (1982). Predicting students' outcomes from their perceptions of classroom psychosocial environment. American Educational Research Journal, 19, 498-518.

FRASER, B.J. & FISHER, D.L. (1986). Using short forms of classroom climate instruments to assess and improve classroom psychosocial environment. Journal of Research in Science Teaching, 23, 387-413.

FRASER, B.J. & WALBERG, H.J. (Eds.) (in press). Classroom and school learning environment. London, Pergamon.

GIDDINGS, G. & HOFSTEIN, A. (1980). Trends in the assessment of laboratory performance in high school science instruction. Australian Science Teachers Journal, 26(3), 57-64.

HAERTEL, G.D., WALBERG, H.J. & HAERTEL, E.H. (1981). Socio-psychological environments and learning: A quantitative synthesis. British Educational Research Journal, 7, 27-36.

HOFSTEIN, A. & LUNETTA, V. (1982). The role of the laboratory in science teaching: Neglected areas of research. Review of Educational Research, 52, 201-207.

LUNETTA, V., HOFSTEIN, A. & GIDDINGS, G. (1981). Evaluating science laboratory skills. The Science Teacher, 48(1), 22-25.

MOOS, R.H. (1974). The social climate scales: An overview. Palo Alto, Calif., Consulting Psychologists Press.

MOOS, R.H. (1979). Evaluating educational environments:Procedures, measures, findings and policy implications. San Francisco, Jossey-Bass.

PICKERING, M. (1980). Are lab courses a waste of time? The Chronicle of Higher Education, 19, 44-50.

TRICKETT, E.J. (1978). Toward a social-ecological conception of adolescent socialization: Normative data on contrasting types of public school classrooms. Child Development, 49, 408-414.

TRICKETT, E.J., TRICKETT, P.K., CASTRO, J.J. & SCHAFFNER, P. (1982). The independent school experience: Aspects of normative environments of single sex and coed schools. Journal of Educational Psychology, 74, 374-381.

Research in Science Education, 1989, 19, 133 - 144

STUDENT UNDERSTANDINGS OF ACIDS AND BASES: A TWO YEAR STUDY

Brian Hand

INTRODUCTION

There have been many studies conducted during this decade which have established that children bring misconceptions into the science class. For example one only has to look at the papers presented at the Second International Seminar on Misconceptions and Educational Strategies in Science and Mathematics at Cornell University (Novak 1987) in order to gain some indication of the number of studies being undertaken.

Driver and Oldham (1985) proposed a constructivist approach to the teaching of science, so that children's misconceptions can be addressed. Using such an approach children are encouraged to become active within the learning process so that they can be involved in challenging and changing their own misconceptions to scientifically acceptable concepts. Minstrell (1984) was particularly concerned with the area of conceptual conflict within the constructivist framework. He was able to demonstrate that when students were placed in a position in which their own misconceptions were unable to explain the phenomena studied, they would change these misconceptions to scientifically acceptable concepts.

Hand and Treagust (1988) previously reported on the use of a constructivist strategy of teaching in relation to the topic "Acids and Bases" taught at the year 10 level. One of the major outcomes from this study was that the strategy increased the ability of students to successfully retain the concepts which they had changed, that is, misconceptions were changed to scientifically acceptable concepts and transferred into the students' belief system. Of further interest, is how long will these concepts be retained? Will they change over time? This paper reports on the re-examination of these concepts with several of the same students after the lapse of a two year period from the original study.

BACKGROUND

There were 60 students in the original study which was conducted at the Year 10 level in 1986. In 1988, 24 of these original students remained at the end of Year 12 and they sat for the 1988 year 10 test on Acids and Bases, which was identical in format to the original paper set in 1986. Of these 24, 14 were interviewed using a semi-structured individual interview format.

There were three science subjects offered to the original Year 10 students which would, or could, have some topic related to 'Acids and Bases'. These were Chemistry, Biology, and Multi-strand Science. During the two years of study (Year 11 and 12) the work covered in relation to Acids and Bases was as follows:

> Chemistry - Acid/Base equilibrium theory was analyzed and thus dealt with acid/base definitions, pH values, acid strength and concentration, and neutralisation. Thus the students will have dealt with the concepts previously covered, albeit in more detail.
>
> Multi-strand Science (MSS) - These students were exposed to a course on hydroponics in which they were required to test for acidity and alkalinity using pH paper. In addition they were required to make solutions of different concentrations and strengths for use in growing seedlings.
>
> Biology - These students were not exposed to any particular study of Acids and Bases during their two year course. Reference was made in passing to particular acid concentrations within the biological systems, however no detailed study was conducted.

Of the five misconceptions which were identified in the original study, four of these were re-examined. These were related to the definition of an acid, the testing for an acid, the difference between acid strength and acid concentration and the process of neutralisation.

THE STUDY

Twenty four Year 12 students, who were part of a Year 10 group taught the topic "Acids and Bases" in 1986, were tested to determine their understanding of the particular concepts learnt during the course of the original unit. The students were given a test based on the initial test format of content and process sections, which had been given to the Year 10 students in 1988. An example of a content item is:

> When two acids of the same concentration are reacted with Magnesium, one reacts violently, whilst the other only very moderately. Why are the reactions different?

An example of a process item is:

> In an experiment in a laboratory you are given two beakers, one containing 20 ml of 1M HCl. In the other you have some 1M NaOH.
>
> (a) How much NaOH would you need to add to the HCl to produce a neutral solution?
>
> (b) Describe carefully how you would test for this neutral solution?

This test was aimed at the same level as the original test given in 1986, as part of the same Year 10 science program. Fourteen of the 24 students were interviewed using semi-structured individual interviews to determine their understanding of the concepts, and their views on the teaching strategy when viewed in hindsight.

At no stage in any of the testing procedures were the students given any advance warning e.g. the students were not given any "swotting time". This was intentional in that the author wanted to elicit what the students knew about the topic. Thus the questions the author wished to address were:-

(1) Are the students' current concepts on Acids and Bases scientifically acceptable?

(2) Have those students who have had some reinforcement by doing more work on Acids and Bases, cemented these concepts into their knowledge system?

(3) In hindsight, do the students' view conceptual conflict learning strategy as a useful approach to learning?

RESULTS

Student responses to test questions on each of the four concepts identified earlier are discussed below:-

The definition of an Acid

This involved the students in being able to give a concise definition of an acid. In conjunction with the concise definition, students were expected to know the properties of an acid. In 1986 students scored very well in answering these questions. The major problem involved giving a concise definition of the term "acid"; however the properties of an acid were easily remembered.

In 1988 these questions were answered in a poor manner. In general, it was only those students who studied chemistry who scored more than 1 out of 3. Nearly all the MSS students failed to answer these questions. These results can be seen in figure 1, where the graphs indicate the percentage of students who scored some marks on the questions. The figure indicates their 1986 mark in relation to their effort in 1988.

Testing for an Acid.

This involved the use of indicators and the pH scale to test for an acid. The author appreciates the narrowness of the questions in that the questions were not asked of the use of other properties of acids in the testing process.

In 1986 students scored extremely well on this question. This question related to the pH scale and universal indicator. Hand (1988a) proposed that the learning of the colours of universal indicator was made easier by linking to the pH scale. This linking promoted the meaningful learning situation. Student interviews at that time (Hand 1988b) supported the fact that students remembered and related to universal indicator much more easily than to litmus and phenolphthalein.

In 1988 two questions were asked. The first, a content question on litmus and phenolphthalein; and the second, a process question on pH values and their relationship to acids. The results of these two questions were interesting. Nearly all the people who answered question one correctly were the chemistry students. However, the second question was answered much better by both the biology and the MSS students. MSS students had been involved with pH levels during the hydroponics component of their course. The biology students had had no major association with pH during their course work. Chemistry students scored well for this question, that is, their results remained consistent with their question one results. These results are graphed in figure 2.

The difference between acid strength and concentration.

This involved the students in understanding the difference between a strong acid and a concentrated acid, that is, the difference between the number of hydronium ions in solution and the ability of an acid to release it's hydronium ions into solution.

In 1986 only 10 of the 24 students scored full marks in describing the difference between concentration and strength. This was one of the two

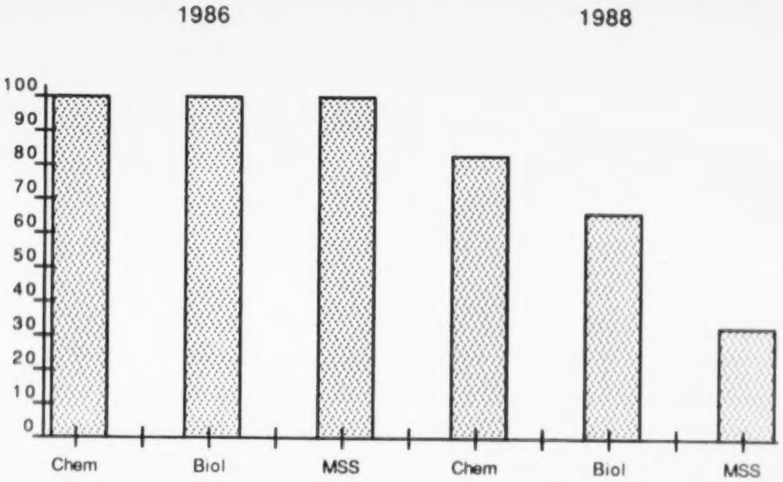


Figure 1: The graph shows the percentage of students scoring at least some marks in questions on the definition of an acid. The graph shows the variation in results between 1986 and 1988.

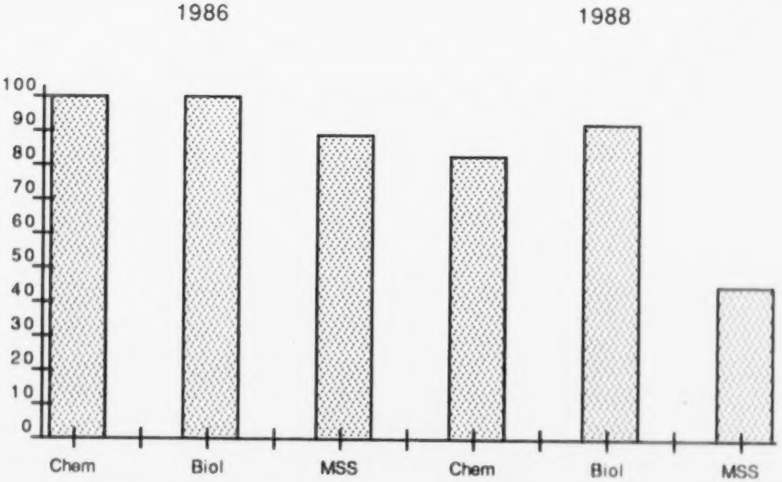


Figure 2: The graph shows the percentage of students scoring at least some marks in questions related to the testing of acids. The graph shows the variation in results between 1986 and 1988.

concepts which were poorly understood, indicating that although the author believed the conceptual conflict had been created, it was not of sufficiently strong significance to cause a change to the students' belief system.

In 1988 there was a marked change in that 17 out of the 24 students scored full marks on defining the difference between acid strength and concentration. However in using this definition, only 12 of the 24 students gained marks, with only 1 gaining full marks. The distribution of students scoring marks on the process questions was 3/7 for biology, 6/9 for chemistry and 3/8 for MSS. Thus approximately 50% of the students in all the subjects scored some marks. This is understandable in the case of the chemistry and MSS students, but not so in relation to the biology students. The biology students had little or no work on Acids or Bases during their course work. These results are shown in figure 3.

The process of neutralisation.

This involved the students understanding that the acids or bases may be neutralised by the addition of a base or an acid, producing water plus salt. In 1986, 20 out of the 24 students scored some marks in both the content and process sections. It is noted, however, that only one student scored full marks in the process section. This indicated that only partial understanding of the concept had occurred.

In 1988, only 10 out of the 24 students scored marks on the content section of the test, whilst only 6 out of the 24 students scored marks on the process section of the test. Those students scoring the marks were mainly the chemistry students. These results can be seen in figure 4.

DISCUSSION

Before discussing the results the author wishes to point out that the results produced must be examined with the realisation that this was not a rigidly controlled experiment. The material covered by the students during their course of study was determined; however, the contact by students with acids and bases outside of the classroom was not monitored. In the original study (Hand 1988b) it was argued that students would have had little exposure to acids and bases in the real world and thus the knowledge gained would be via the classroom. This argument could be extended to the two year period between 1986 and 1988. Thus, in general, most students would not have been overly exposed to the concepts of acids and bases in the real world, hence knowledge gained and/or altered was anticipated to be a direct result of the learning which occurred in the subjects studied during the two year period

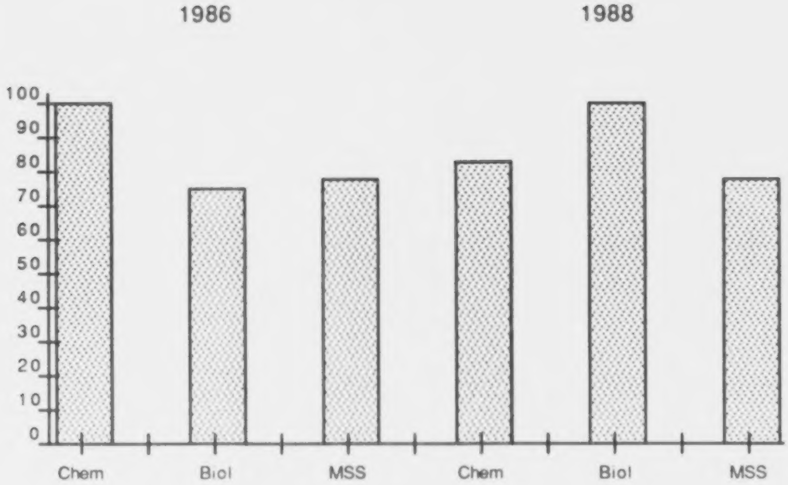


Figure 3a: The graph shows the percentage of students scoring at least some marks in questions related to the difference between acid strength and the concentration of an acid. The graph shows the variation in results between 1986 and 1988.

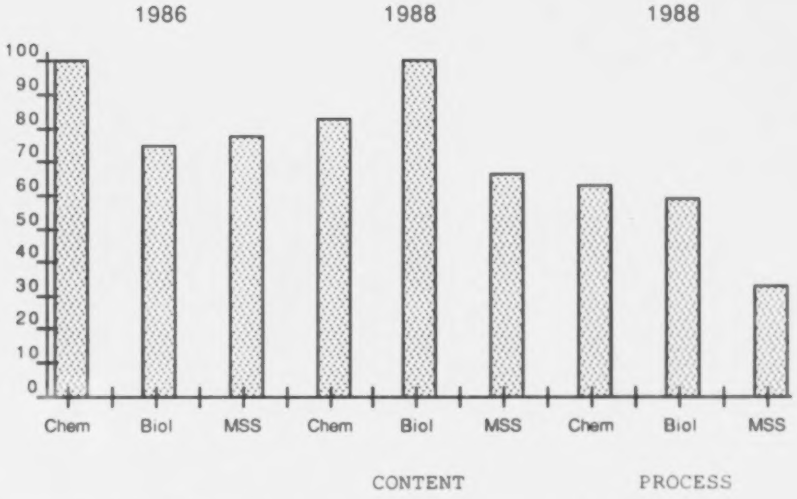


Figure 3b: The graph shows the percentage of students scoring at least some marks in questions related to the difference between acid strength and the concentration of an acid. The results for 1988 indicated the difference in scores between the content and process sections of the test.

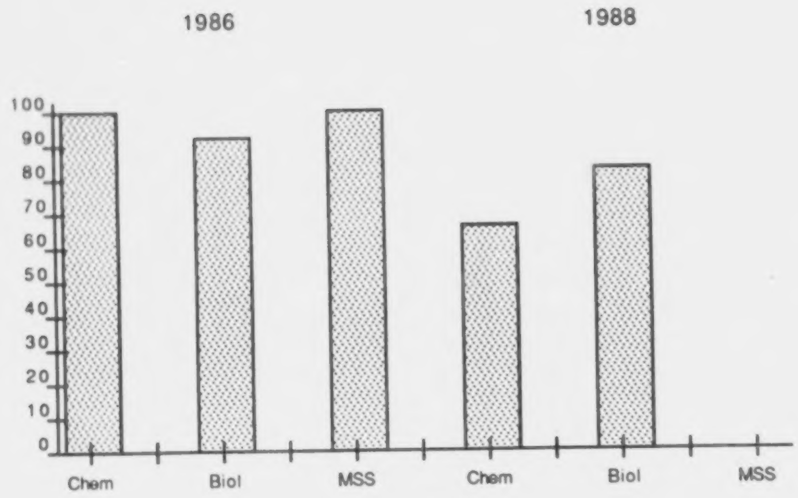


Figure 4: The graph shows the percentage of students scoring at least some marks on questions related to the process of neutralization. The graph shows the variation in results between 1986 and 1988.

under review.

The normal distribution of students at the school was such that the best students, or those who achieved the better results in Year 10, choose to do chemistry. Biology was undertaken by the above average to average ability students, while MSS was taken by the average to below average students.

On examination of the graphs of the results, an interesting trend appears. Before an examination of the results was conducted the expectation was that the chemistry students would score higher than the other students due to the greater exposure to acids and bases.

From Figure 1 it would appear that the chemistry students as a group performed the best. Students were asked a content question (recall of knowledge), and due to the fact that the chemistry students had had a section of work on acids and bases, this was not unexpected. However, in all other areas the biology students scored better than the chemistry students; both groups were much better than the MSS students. This was the unexpected result. Why should biology students, who did not have anywhere near the re-inforcement experience of the chemistry students, score better than the chemistry students?

One possible explanation may be the manner in which the students and the subject manner were handled. The chemistry course was taught using a traditional method, that is, a teacher-centred approach involving talk and chalk sessions with the appropriate practical sessions. The biology taught was the Web of Life course which is much more of an inquiry based strategy than the chemistry course. Thus the students doing biology would have been more accustomed to a student-centred approach involving the process of linking knowledge learnt. The teaching strategy used with the chemistry students was not orientated towards a student centred approach and thus meaningful learning was not the aim of the strategy, rather the aim was the learning of the content covered.

Thus the chemistry students would be orientated to learning to achieve a result, with understanding an intended by product. This learning therefore is more rote than meaningful and as a result may have caused interference to occur to the knowledge already stored (Biggs & Telfer, 1986). Biology students were encouraged to learn meaningfully and thus promote linking of knowledge. As a result there may be less interference, due to less material being covered in relation to acids and bases, thus allowing for better recall.

Another possible explanation may be that whenever the biology students were exposed to the term acid, the knowledge recalled would have been the concept of an acid gained in year 10, thus allowing for re-inforcement of the scientifically correct concept. Pines and West (1986) state that constant revisiting of the new concept is required to ensure that it is integrated into the students' belief system. Thus when the biology students were exposed to the term acid they were not having any interference from any new definitions, rather they were recalling the correct concept. When discussing such topics as acid rain, acid in the digestive system or the role of buffers in the body students were most likely recalling and using scientifically correct concepts.

The MSS students' results could be explained by there not being sufficient re-inforcement, that is, sufficient practice, on using the learnt concepts in 1986 to allow successful integration (Pines & West, 1986). These students were not involved in strategies in 1987 and 1988 which would involve them in their own learning. This was reflected in their attitude to this subject, which, for some, was very poor.

The most unexpected result was the increase in the number of students showing some understanding on the difference between acid concentration and strength. A possible explanation for this would be the involvement of all the students in making their own solutions for their experiments. Another possible explanation may be that some students have pools at home and thus are involved in controlling concentration of solutions. However Figure 3 shows that although there has been an increase in knowledge (answers on the content questions) there is not the same increase in the understanding (answers on the process questions). This would indicate that even though they knew how to make up solutions they were still not sure exactly what they were doing.

STUDENT PERCEPTIONS OF CONSTRUCTIVISM

When asked to comment on how they felt about the strategy of constructivism when viewed in hindsight, most students were positive. A couple of students felt that the strategy did not really suit their style of learning. These students were rote learners and were much more comfortable when they were able to copy information from the blackboard. Most students, however claim that they enjoyed the opportunity to be able to work out for themselves, in their own words, what concepts they were actually dealing with. Some students' responses to the question of whether they liked the strategy are:

> "Yes, you realised that your first idea was wrong and then you arrived at what was right".
>
> "Yes, it was interesting to go through and prove if you were

> right or wrong".
> "You work out possibilities for an answer or eliminate the others so you get the right answer".

Other students were not so positive, for example:-

> "I can't use my own words, I have to be told something".
> "No, I still prefer to take notes".
> "Because they [the concepts] were not on the board. You didn't have notes to refer back to".

Most of the students interviewed were of the opinion that the strategy was useful and that they had been actively involved in determining their own concepts. This, they commented, allowed them to gain more understanding because they were learning to use their own terminology not the teacher's or some textbook.

CONCLUSION

This study had indicated that further research needs to be done into the examination of how subsequent learning will interact with knowledge previously gained. Does the learning of new knowledge in relation to previously understood knowledge cause interference (Biggs & Telfer 1986) or does it result in some confusion culminating in lack of linkages (Osborne & Freyberg, 1985)? Can the benefits of constructivism be built upon when using other strategies? These are some of the questions which arise from the results obtained in this study. This study does not provide any definitive solution to the questions; however it does show that long term retention of concepts learnt using a constructivist strategy does occur.

REFERENCES

BIGGS, J.B. & TELFER, R. (1986) The Process of Learning. Sydney: Prentice Hall of Australia.

DRIVER, R. & OLDMAN, V. (1985) A Constructivist Approach to Curriculum Development in Science. Paper prepared for the symposium "Personal Construction of Meaning in Educational Settings", BERA, Sheffield.

HAND, B. (1988a) Is conception conflict a viable teaching strategy? : the students' viewpoint. Australian Science Teachers Journal, 34 (4) 22-26.

HAND, B. (1988b) Acids and Bases : Can Conceptual Conflict Change Misconceptions? Unpublished masters thesis. Perth: Curtin University.

HAND, B. & TREAGUST, D. (1988) Application of a conceptual conflict strategy to enhance learning of acids and bases. Research in Science Education, 18, 53-63. Sydney: Australia.

MINSTRELL, J. (1984) Teaching for the development of understanding of ideas: forces on moving objects. In Anderson, C.W. (Ed.) Observing Science Classrooms : Observing Science Perspectives from Research and Practice. ERIC Ohio State University Columbus, Ohio.

NOVAK, J.D. (1987) Proceedings of the Second International Seminar on Misconceptions and Educational Strategies in Science and Mathematics. Ithaca, Cornell University.

OSBORNE, R. & FREYBERG, P. (1985) Learning in Science : The Implications of Children's Science. Sydney, Heinemann.

PINES, A.L. and WEST, L.H.T. (1986) Conceptual understanding and science learning : an interpretation of research within a source-of-knowledge framework. Science Education, 70, 583-604.

Research in Science Education 1989, 19, 145 - 154

TECHNIQUES USED BY PRIMARY SCHOOL PUPILS IN DRAWINGS DURING SCIENCE ACTIVITIES

Dorothy Hayes,
David Symington.

INTRODUCTION

This paper reports part of a study concerned with drawings completed by junior primary school pupils during science lessons. It deals with the techniques that pupils used to communicate information regarding their investigations, and the source and adaptation of those techniques.

Drawing is an activity that is frequently included in junior level science lessons. It is perceived as a simple, practical means of recording the pupils' observations. The latest science curriculum document produced by the Victorian Education Ministry "The Science Framework P - 10" (Ministry of Education, 1987) refers to drawing as a means of evaluation.

Further, it is seen as an end as well as a means. For example, in "Science in the Primary School" (Education Department of Victoria, 1981), it is stated that by the end of year two the pupils should be able to "record information using tables, models, paintings and drawing" (Page 22).

In these documents, however, there is no guidance given to teachers as to methods of using drawings effectively in science lessons. Teachers are not informed about when to use drawings, or how to help the pupils to develop drawing techniques and skills.

To find any attempt to assist teachers in this area it is necessary to go back to the Nature Study days. In the 1930's two books were published by the Gould League of Bird Lovers in Victoria to assist teachers and bird observers in developing drawing skills.

The purpose of these books Sketches of Australian Birds was to assist a wide range of people, including children, to study native birds. These books proposed the learning of drawing techniques through instruction. The measurements, colours and construction lines to be recorded were shown in great detail.

Young pupils were included in the group who were to be encouraged to use these sketchbooks. Expectations were not as high as those for the adults;

the children were to draw a simple outline and use coloured chalk to complete the drawing.

As stated previously, in Victoria no publications since then have included information for teachers about their role in relation to pupils' drawings in science lessons. Is it because it is perceived as a simple activity, or is it believed that the pupils have all the techniques they need, so no instruction is necessary?

RESEARCH QUESTIONS

The study reported in this paper is part of an attempt to gather data that will provide teachers with information on effective ways of using drawings in science activities.

The study addressed the following questions:

*What techniques are used by the pupils?
*Where do the techniques come from?
*Do the techniques spread to other pupils when used?
*How are the techniques adapted by the pupils?

CONTEXT OF STUDY

This research study was based on part of the normal Grade 2 science program. The topic of study was "Oils". The pupils participated in a sequence of five lessons using a modified Interactive Teaching Approach (Biddulph & Osborne, 1984). Drawing was used as the primary method for the pupils to communicate what they had done, and observed, during each lesson. The teacher did not teach the pupils any drawing techniques.

THE LESSONS

As the data collected relate to Lessons 2 and 3, only Lessons 1,2 and 3 will be described here.

Lesson 1. The first lesson was designed to clarify and explore the pupils' ideas about the topic "Oils", and provide the teacher with information regarding the pupils' knowledge and understanding of this topic. During the lesson the pupils looked at oil samples, discussed oils, asked questions and completed a drawing that would assist them in identifying each of the six different oil samples at the start of the second lesson.

Lesson 2. This lesson commenced with a matching/identification activity. The pupils worked in their groups of 4, and most experienced no difficulty in using their drawings to determine which oil was which. After making their identification the pupils informed the teacher, or one of the observers, of the reasons for their ease or difficulty in completing the activity.

After reading the question that was to be investigated, "What happens when you mix oil and water?", they used a drawing to predict what they thought the result would be. The pupils then worked in groups of 4 to find the answer.

When they had completed their investigation the pupils were asked to do a drawing to show their peers and the teacher what they had done and what they had observed.

Each group of 4 children reported to the rest of the class by showing their pictures without any supporting verbal comment. The pupils in the class had the opportunity to describe their interpretation of the drawings. The reporters then had the chance to react to these interpretations.

The outcomes were compared to predictions and any new questions were recorded.

Lesson 3. This lesson began with a short discussion of the results collected during lesson 2. Some pupils had also conducted simple experiments at home. These pupils explained to the class what they had done and shared their results.

The question to be investigated during this lesson was "What would happen if we mixed baby oil, olive oil and engine oil together?" The pupils again used a drawing to show their predictions. Working in groups of 4 the pupils completed the investigation. The pupils were again asked to do a drawing to show their peers and the teacher what they had done, their observations and results.

These drawings were again shown to the class, each group having a turn. No verbal report was given, but the class members talked about their interpretation of the drawings.

Results were compared to predictions and new questions were recorded.

DATA GATHERING

The data collected during this study were:

*the pupils' drawings;

* notes made by observers during the lessons;

*interviews with the pupils after each lesson.

The Drawings. These were collected after each lesson. They had been used as the basis of communication in the classroom after the investigation. They were also used as the basis for the interviews of the pupils after the lesson.

Observers' Notes The observers were the class teacher and three Victoria College first year student teachers. Each observed a group of children and recorded the dialogue and any other significant events during each lesson. An observer's guide sheet was supplied prior to each lesson with the activities listed and indicating what type of data should be recorded.

Interviews. The interviews were conducted on the morning following the lesson. During the interviews the pupils were asked questions related to:

i. the techniques they had used;
ii. the source of the techniques.

After lesson 2 the interviews were conducted on a group basis. After lesson 3 the interviews were conducted on an individual basis.

As stated earlier in this paper the focus for this study was the techniques the children used in their drawings. The 4 research questions provided the framework for analyses of the data.

(a) What techniques are used by the pupils?

When interviewed after lessons 2 and 3, the pupils identified the techniques that they had included in their drawings. This information is shown in Table 1.

As can be seen in Table 1, six of the techniques used and identified after lesson 2 were again used in lesson 3. Three techniques were not used again. The pupils who had used these techniques in lesson 2, when interviewed after lesson 3, said that they hadn't used them again because they had either found a technique that worked more effectively or because the techniques they had used in lesson 2 had not assisted the other pupils in working out what had taken place during the investigation. These pupils were among the ones who used more detail and made their drawings bigger and clearer.

(b) Where do the techniques come from?

After each lesson the pupils were interviewed and asked where the techniques they had used had originated. These results are shown in Table 1.

TABLE 1

Reported origins of the techniques used by the pupils in their drawings

Technique	No. of children reporting use of the technique	Reported source of the technique					
		School		Out of School		Own Idea	
		Lesson 2	Lesson 3	Lesson 2	Lesson 3	Lesson 2	Lesson 3
i. Using a numbering system	24	9	10	2	-	1	2
ii. Using labels to explain drawings	18	8	9	-	-	1	-
iii Using arrows to show sequence or movement	12	5	1	1	-	4	1
iv. Using colour to assist in identification	12	-	2	-	-	10	-
v. Using sentences	5	3	1	1	-	-	-
vi. Using code letters to identify drawing parts	3	-	1	1	-	1	-
vii. Using letters of alphabet to show sequence	2	2	-	-	-	-	-
viii. Using small pictures to show observations	1	-	-	-	-	1	-
ix. Using line to divide page into sections for drawings	1	1	-	-	-	-	-
x. Using bigger and clearer drawings	8	-	-	-	-	-	8
xi. Using more detail in drawings	1	-	-	-	-	-	1

In Table 1 it can be noted that, when interviewed after lesson 2, the pupils stated that the majority of techniques they had used had been seen or used previously at school. Others were based on ideas they had noticed out of school. These included the use of numbers to show order, this technique was seen on TV, and arrows on road signs. A child reported that people wear tags at 'Little Athletics' to show order and she had adapted this idea. Quite often the pupils suggested that a technique, e.g. use of colour, was their own idea.

When interviewed after lesson 3, the majority of pupils again stated that the techniques they had employed had been seen or used at school. Again a number of pupils used techniques which they reported as their own idea, the most noteworthy being to make their drawings bigger and clearer.

(c) Do the techniques spread to other pupils when used?

Data related to this question were collected during the interviews and are presented in Table 2.

TABLE 2

Spread of techniques among the pupils

Technique	No. of chn. reporting use of the technique	Reported source of the technique		
		Use by chn. in other topic	Used by chn. in this topic	
			in same group	in other groups
i. Numbers	24	-	8	8
ii. Labels	18	1	1	5
iii. Arrows	12	3	1	2
iv. Colour	12	-	1	1
v. Sentences	5	-	-	1
vi. Code letters	3	-	-	1

It appears that several techniques were used by pupils as a result of seeing them used by their peers. This indicates a spread of techniques through observation. For example over half the pupils who had used numbers in their drawings had seen other pupils using this technique. About a third of the pupils used labels in their drawings as a result of seeing this technique used by other pupils.

During the interviews the researcher recorded the pupils' ideas on the source of the techniques they had used. Some extracts from these interviews are shown in Table 3.

(d) How are the techniques adapted by the pupils?

A number of the techniques that the pupils used in their drawings had been adapted by the pupils to fulfil a specific purpose. These included the use of arrows and numbers. During the interviews the children said where they had seen the technique and how it had been adapted. Some of these are reported in Table 4.

Many pupils who used numbers in their drawings said that they had seen them before on pages in books or had seen them used as a numbering system on worksheets at school. These pupils used numbers in their drawings to show sequence or the number of drawings completed.

CONCLUSION

It is apparent from the data that pupils use a wide variety of techniques to aid the clarity of their drawings and that they are able to discriminate between them.

The data support the value of the teaching method used, where drawings were used as the principal means of communication between the children.

The study has shown how, without any teacher instruction on drawing techniques, the children have been able to identify and adapt ones which they see as meeting their requirements.

The study has established one teaching method which, following further investigation, could be presented to teachers as a useful strategy during science lessons.

TABLE 3

Extracts from interviews which reflect the spread of techniques amongst the children.

Used by children in other topic

Andrew: "I used arrows to show what went in here. I saw arrows on other people's work when we were doing snails."

Used by children in same group

Sarah: "Ben shared his idea about drawing four pictures with the other people in our group. The girls used Ben's idea. Robert sort of used Ben's idea."

Clare: "I added numbers to show the order that we did it. I saw Katie and Ryan using numbers and I thought it was a good idea."

Used by children in other groups

Jessica: "I used numbers to show the order of what I did. I saw them on Sarah's and Anna's work last time."

Ryan: "I used numbers to show the order of what we did, I saw them on Stefan's drawing last time."

TABLE 4

Extracts from interviews which reported on the source and adaptation of the techniques.

Source of the technique - School

Ben: "I used arrows to show the other children where the oil and water was. The idea came from when we were doing snails and other people used them to show the snail moving."

"I used arrows again but this time I used them to show movement of oil, not just for labels."

James: "I used numbers to show the order of things. I had seen and done exercises on ordering in class."

Laura: "This time I used numbers to show the sequence, these were better than 1st. to 4th. I saw that on Stefan's work."

Source of the technique - Out of School

Laura: "I used the numbers 1st. to 4th. to help the other children to know the order. Sometimes at races, (Little Athletics) you see people wearing tags."

Claire: "I used arrows so people would know which is which. I have seen arrows used as pointers on road signs."

REFERENCES

BIDDULPH, F. AND OSBORNE, R. (1984) Making Sense of our world: an Interactive Teaching Approach. Hamilton (N.Z.), S.E.R.U., University of Waikato.

EDUCATION DEPARTMENT OF VICTORIA (1981) Science in the Primary School - Volume 3. Implementing Science: Preparatory Year to Year 3. Melbourne, Victorian Government Printer.

MAY, R. HAMILTON (date unknown) Sketches of Australian Birds. Melbourne, Gould League of Bird Lovers.

MINISTRY OF EDUCATION (SCHOOLS DIVISION), VICTORIA (1987) The Science Framework: P-10. Melbourne, Victorian Government Printer.

Research in Science Education 1989, 19, 155 - 164

INFLUENCE OF SOCIO-CULTURAL FACTORS ON SECONDARY SCHOOL STUDENTS' ATTITUDE TOWARDS SCIENCE

Olugbemiro J. Jegede and Barry Fraser

INTRODUCTION

Attitude is a complex and multidimensional construct (Germann, 1988) which provides the vehicle through which everyday experiences are interpreted. Its central role in human behaviour has been shown since the time of Thomas and Znaniecki (1918) through to Gardner (1975) and to Shrigley (1983), to exercise considerable influence in all endeavours. For instance, Gardner's (1975) view that the development of attitude should be a central purpose of science education has received considerable support from other workers, as evidenced by the amount of literature that has been generated on the issue (e.g., Keeves, 1975; Robinson, 1980; Munby, 1983, Schibeci, 1984; Blosser, 1984; Haladyna and Shaughnessy, 1982). The classic work of Bloom and his associates on The Taxonomy of Educational Objectives II: The Affective Domain and the inclusion of affective items in the National Assessment of Educational Progress in the United States of America (NAEP, 1978; Yager & Yager, 1985 and Barrington & Hendricks, 1988) serve to reinforce affective objectives as being of great importance. This might have been partly responsible for a trend which emerged world-wide in the post-Sputnik era science curriculum materials in which teaching towards and evaluating affective objectives formed a composite part of science education particularly at the secondary level.

Several researchers have shown the influence of school and non-school environment variables on students' attitude towards science. Keeves (1975), Ormerod and Duckworth (1975), Bloom (1976), Haladyna and Shaughnessy (1982), Khan (1969), Marjoribanks (1976), Simpson and Troost (1982), Cannon and Simpson (1985), Talton and Simpson (1987), Barrington & Hendricks (1988) and Germann (1988) have concluded from their various studies that attitude towards science is an important predictor of achievement.

With regards to classroom pyschosocial characteristics, positive associations have been reported between measures of classroom climate and attitudes to science by Lawrenz (1976), Walberg (1969), Fraser and Butts

(1982), Fraser and Fisher (1982), Haladyna, Olsen and Shaughnessy (1982), Lin and Crawley (1987), Jegede, Fraser and Agada (1989) and Fraser (1989). An aspect of psychosocial climate which has been found to affect the learning of science relates to certain socio-cultural factors which learners, especially in non-western societies, bring into the classroom from their traditional culture (Jegede & Okebukola, 1988; Ogunniyi, 1988). Jegede and Okebukola's (1988) study has isolated the five socio-cultural factors of Authoritarianism, Goal Structure, African Worldview, Societal Expectation and Sacredness of Science, which need to be taken into account in the teaching of science in traditional societies. For science education to be comprehensively effective, it must take cognizance of the cultural context of the society which provides its setting and whose needs it attempts to satisfy. It appears, however, that little attention has been paid to socio-cultural aspects of classroom environment in the literature.

The information emerging from the very few studies on socio-cultural factors (Jegede, 1987; Jegede and Okebukola, 1988; Okebukola and Jegede, 1989; Ogunniyi, 1988), suggests that science learning can be predicated on socio-cultural factors influencing the learner, and attitude research has shown that attitudes determine science learning. Consequently, it is reasonable to hypothesize that a relationship between socio-cultural factors and attitudes towards science also might exist in the science classroom. The cultural context of the learner, which is a complex web of linguistic, social, political, economic, philosophical and religious entities (Wilson, 1981), determines and shapes attitudes. No study, to date, provides insight into the culturally bound nature of attitudes and the influence that socio-cultural factors have on students' attitudes toward science.

The purpose of the present study was to examine the relationship, if any, between attitudes toward science and socio-cultural factors in a non-western classroom environment.

METHOD

Seventeen classes in six junior secondary schools of Benue state in Nigeria were selected using a stratified random sampling procedure yielded two schools each representing the three major cultural groups in the state. Altogether, the sample consisted of 586 class 3 (grade 9) junior secondary students (337 boys, 249 girls; mean age = 14.1 years), with an average of 32 pupils per class.

The Test of Science-Related Attitudes (TOSRA), developed by Fraser (1978), was used to measure students' attitudes towards science. The instrument has the seven subscales of Social Implications of Science, Normality of Scientists, Scientific Inquiry, Adoption of Scientific Attitudes, Enjoyment of Science Lessons, Leisure Interest in Science and Career Interest in Science. The mean interscale discriminant validity coefficient ranged from 0.13 to 0.40 while the subscale alpha reliability estimates ranged from 0.64 to 0.92.

The Socio-Cultural Environment Scale (SCES), developed by Jegede and Okebukola (1988), consists of five subscales of Authoritarianism, Goal Structure, African Worldview, Societal Expectations and Sacredness of Science. The SCES, has subscale reliability estimates that ranged from 0.88 to 0.96 and mean interscale discriminant validity coefficients ranging from 0.14 to 0.45.

The TOSRA and SCES instruments were administered to the sample within a four-week period. The test instruments were administered to the subjects during their normal science lessons to minimize disruption of the school timetable.

RESULTS AND DISCUSSION

The descriptive results shown in Table 1 indicate that students' highest subscale mean scores on the SCES on Societal Expectation (X=14.91, S.D = 2.34) and lowest subscale mean score on African Worldview (X = 11.92, S.D = 1.86). For TOSRA subscales, Table 2 shows that the highest subscale mean score was on Normality of Scientists (X=43.34, S.D = 4.95) while the lowest subscale mean score was on Social Implications of Science (X= 35.59, S.D = 5.27).

TABLE 1

Descriptive Information on SCES subscales

Subscales	Mean	S.D.
Authoritarianism	13.78	1.87
Goal Structure	13.39	1.95
African Worldview	11.92	1.86
Societal Expectation	14.91	2.34
Sacredness of Science	12.58	1.87

TABLE 2

Descriptive Information on TOSRA subscales

Subscales	Mean	S.D.
Social Implications of Science	35.59	5.27
Normality of Scientists	43.34	4.95
Attitudes to Scientific Inquiry	37.43	6.45
Adoption of Scientific Attitudes	36.93	5.34
Enjoyment of Science Lessons	41.03	5.92
Leisure Interest in Science	40.71	6.05
Career Interest in Science	38.05	6.15

In order to investigate the relationship between socio-cultural factors and science related attitudes, Pearson product moment correlations were computed between TOSRA and SCES scale scores.

TABLE 3
Correlations between Test of Science Related Attitude and
Socio-Cultural Factor Scales
SCES SCALES

TOSRA SCALES	Authoritarianism	Goal Structure	African Worldview	Societal Expectation	Sacredness of Science
Social Implications of Science	0.26*	0.20*	0.06	0.27*	0.03
Normality of Scientists	0.21*	0.18*	0.04	0.14*	- 0.05
Attitudes to ScientificEnquiry	0.22*	0.22*	0.07*	0.23	0.01
Adoption of Scientific Attitude	0.26*	0.25*	0.08*	0.19*	0.06
Enjoyment of Science Lesson	0.30*	0.27*	0.09*	0.36*	0.10*
Leisure Interest in Science	0.34*	0.29*	0.09*	0.40*	0.11*
Career Interest in Science	0.29*	0.23*	0.12*	0.42*	0.11*

*significant at p < .01

The results shown in Table 3 indicate that out of the 35 correlation coefficients, 29 proved to be significant (p < .01). Consistent patterns were found for almost all the subscales except Sacredness of Science subscale of the SCES, which had no significant relationships with Social Implications of Science, Normality of Scientists and Adoption to Scientific Attitudes. The other subscale that showed no relationships with Social Implications of Science and Normality of Scientists subscales was the African Worldview subscale.

The association between socio-cultural factors and attitudes towards science seems to suggest that the socio-cultural factors that Nigerian students carry into the classroom influence their attitudes towards science. Socio-cultural factors, just like attitudes, are bidirectional and can be represented by an unfavourable as well as favourable valence (Shrigley, Kobala & Simpson, 1988). An unfavourable disposition to both or either would have serious consequences for the learning of science.

Many writers and research workers in the area of attitudinal studies in Africa have stressed the paramount role that the right kind of attitudes towards science could play in technological advancement of African nations (Taiwo, 1981). In the same light, Cole (1975) has stated that :

> Many development programmes in which governments (of developing countries) have attempted to improve say, the health and social conditions of the people, have failed because of outright antagonism of the people due to conflict between traditional culture and scientific culture being introduced....

Attitudes are learned (Bogardus, 1960; Fleming, 1967; Gardner, 1975) and represent emotional filters through which our environment is ordered (Katz, 1960). Viewed in relation to the results of this study, therefore, it is possible that the negative attitudes which children in non-western societies like Nigeria manifest towards science come about as a result of the inhibitory effect of socio-cultural factors. This therefore makes the relationship of socio-cultural factors and attitudes towards science both correlational and literal, indicating the realities of the problems which learners of science in traditional cultures have to grapple with in the classroom.

CONCLUSIONS AND IMPLICATIONS

This study investigated the influence of socio-cultural factors on secondary school students' attitudes towards science in a non-western environment. There is evidence from the results of the study that socio-cultural factors and attitudes are related and influence each other in the learning of science.

Results from this study seem to point to the need to examine the psychosocial environment in science classrooms in traditional cultures and of learners with traditional background in pluralistic communities of the western world. A further implication arising from the study is the need for curriculum developers, science teachers and publishers to give more consideration to the question of teaching the European model of cartesian science in the African cultural context. It would seem plausible to presume that presenting science concepts using the particular world view developed by Western scientists to African pupils engenders attitude-related problems in a culturally dissonant group.

The importance of the role which science and technology play in the development of a nation in contemporary times are obvious to all. The global movement towards science for all underscores this. However, the potential gains derivable from the science for all philosophy might come to naught with particular reference to non-western societies if the conflict between 'traditional culture' and 'scientific culture' engendered by unfavourable attitudes which emanate from socio-cultural factors are not resolved. Consequently, there is a need to attempt to understand and resolve the crisis of conflict in learners of science within traditional environments. This undoubtedly would involve more research to bring to focus the nature of the conflict and the best possible method for its resolution.

REFERENCES

BARRINGTON, B.L., & HENDRICKS, B. (1988). Attitudes toward science and science knowledge of intellectually gifted and average students in third, seventh and eleventh grades. Journal of Research in Science Teaching, 25 679-688.

BLOOM, B. S. (1976). Human characteristics and school learning. New York, Mcgraw Hill.

BLOSSER, P. E. (1984). Attitude research in science education. ERIC Clearinghouse of Science, Mathematics and Environmental Education Information Bulletin, No.1. Ohio State University, Columbus, OH.

BOGARDUS, E. S. (1960). The development of social thought. New York, Longmans, Green and Company.

CANNON, R. K. & SIMPSON, R. D. (1985). Relationships among attitude, motivation and achievement of ability grouped, seventh grade, life science students. Science Education, 69, 121-138.

COLE, M. J. (1975). Science teaching and science curriculum development in a supposedly non-scientific culture. West African Journal of Education, 19, 312-322.

FLEMING, D. (1967). Attitude: The history of a concept. Perspectives in American History, 1, 287-365.

FRASER, B. J. (1978). Test of science related attitudes. Melbourne, Australian Council for Educational Research.

FRASER, B. J. (1976). Classroom environment. London: : Croom Helm

FRASER, B. J. (1989). Learning environment research in science classrooms : Past progress and future prospects. Washington, National Association for Research in Science Teaching.

FRASER, B. J. & BUTTS, W. L. (1982). Relationship between perceived levels of classroom individualization and science related attitudes. Journal of Research in Science Teaching, 19, 143-154.

FRASER, B. J. & FISHER, D. L. (1982). Predicting students' outcomes from their perceptions of classroom psychosocial environment. American Educational Research Journal, 19, 498-518.

GARDNER, P. L. (1975). Attitudes to science : A review. Studies in Science Education, 2, 1-41.

GERMANN, P. J. (1988). Development of the Attitude Toward Science in School Assessment and its use to investigate the relationship between science achievement and attitude toward science in school. Journal of Research in Science Teaching, 25, 689-703.

HALADYNA, T. & SHAUGHNESSY, J. (1982). Attitudes toward science; A quantitative synthesis. Science Education, 66, 547-563.

HALADYNA, T., OLSEN, R. & SHAUGHNESSY, J. (1983). Correlates of class attitude toward science. Journal of research in Science Teaching, 20, 311-324.

JEGEDE, O. J. (March, 1987). Socio-cultural correlates of anxiety in science classrooms : A preliminary report. Paper presented as a contribution to the International Roundtable Exchange at the National Convention of the National Science Teachers' Association. Washington, D.C.

JEGEDE, O. J. & OKEBUKOLA, P. A. O. (1988). An educology of socio-cultural factors in science classrooms. International Journal of Educology, 2(2), 93 - 107.

JEGEDE, O. J., FRASER, B. J. & AGADA, D. S. (1989). Relationships among classroom climate, science related attitudes and socio-cultural factors among junior secondary students in Nigeria. Unpublished paper. Curtin University of Technology, Perth. Western Australia.

KATZ, D. (1960). The functional approach to the study of attitudes. Public Opinion Quarterly, 24,163-204.

KEEVES, J. P. (1975). The home, the school, and achievement in mathematics and science. Science Education, 59, 439-460.

KHAN, S. B. (1969). Affective correlates of academic achievement. Journal of Educational Psychology, 60, 216-221.

LAWRENZ, F. (1976). The prediction of student attitude toward science from student perception of the classroom learning environment. Journal of Research in Science Teaching, 13(6), 509-515.

LIN, B. & CRAWLEY, F. E., II (1987). Classroom climate and science-related attitudes of junior high school students in Taiwan. Journal of Research in Science Teaching, 24 579-591.

MARJORIBANKS, K. (1976). School attitudes, cognitive ability, and academic achievement. Journal of Educational Psychology, 68, 653-660.

MUNBY, H. (1983). An investigation into the measurement of attitudes in science education. Columbus, OH, SMEAC Information Reference Center, Ohio State University. (ERIC Document Reproduction Service No. ED 237-347).

NATIONAL ASSESSMENT OF EDUCATIONAL PROGRESS. (1978). The third assessment of science, 1976-77. Report No. 08-5-08, May, 1978. Denver, CO, 1860 Lincoln Street.

OGUNNIYI, M. B. (1988). Adapting western science to traditional African culture. International Journal of Science Education, 10, 1-9.

OKEBUKOLA, P. A. O. & JEGEDE, O. J. (1990). Eco-cultural influences on students' concept attainment in science. Journal of Research in Science Teaching. (in press)

ORMEROD, M. B. & DUCKWORTH, D. (1975). Pupils' attitude to science. Slough, Berks, NFER.

ROBINSON, J. (1980). Attitudes of students towards science in test schools using human sciences. Journal of Research in Science Teaching, 17. 233-245.

SCHIBECI, R. A. (1984). Attitude to science: An update. Studies in Science Education, 11, 26-59.

SCHIBECI, R. A. & RILEY, J. P. (1986). Influence of students' background and perceptions on science attitudes and achievement. Journal of Research in Science Teaching, 23, 177 187.

SHRIGLEY, R.L. (1983). The attitude concept and science teaching. Science Education, 67, 425-442.

SHRIGLEY, R. L., KOBALLA, T. R. & SIMPSON, R. D. (1988). Defining attitude for science educators. Journal of Research in Science Teaching, 2, 659-678.

SIMPSON, R. D. & TROOST, K. M. (1982). Influences on commitment to and learning of science among adolescent students. Science Education, 66. 763-781.

TAIWO, A. A. (1981). In search of a feasible strategy for the inculcation of scientific attitudes in the African society. Journal of the Science Teachers' Association of Nigeria, 19, 17-28.

TALTON, E. L. & SIMPSON, R. D. (1987). Relationships of attitude towards classroom environment with attitude toward and achievement in science among tenth grade biology students. Journal of Research in Science Teaching, 2, 659-678.

THOMAS, W. & ZNANIECKI, F. (1918). The Polish peasant in Europe and America. Chicago, University of Chicago Press.

WALBERG, H. J. (1969). Predicting class learning: An approach to the class as a social system. American Educational Research Journal, 6, 529-542.

WILSON, B. (1981). The cultural context of science and mathematics education. Studies in Science Education, 8, 26-44.

WILLSON, J. L. (1983). A meta-analysis of the relationships between science achievement and science attitude: Kindergarten through college. Journal of Research in Science Teaching, 20, 839-850.

YAGER, R. E. & YAGER, S. O. (1985). The effect of schooling upon understanding of selected terms. Journal of Research in Science Teaching, 22, 359-364.

Research in Science Education 1989, 19, 164 - 173

TEACHING TECHNOLOGICAL APPLICATIONS IN THE PHYSICS CLASSROOM

A.T. Jones and C.M. Kirk

INTRODUCTION

This paper reports on research into the development of a teaching sequence for introducing technological applications into a traditional school physics curriculum. The research is illustrated by reference to a teaching package on electrical capacitance and is part of a much wider study of physics education carried out recently (Jones, 1987). Background to the teaching sequence and its evaluation was provided by exploring students' views on traditional physics lessons, different methods of introducing technology, and a theory of learning on which to base the introduction of technological applications.

BACKGROUND

There has been a good deal of international research indicating that school physics is often remote from the student's real world and that one method of bridging this gap is to introduce technological applications (for example, see Dowdeswell, 1979; Layton, 1973; Fensham, 1985; Claxton, 1984; Casimir, 1976).

Physics curricula traditionally taught in New Zealand senior secondary school classes (Department of Education 1972, 1973) emphasise the theoretical and experimental aspects of the subject. There is evidence that New Zealand students perceive school physics as difficult, unenjoyable, mathematical and of limited application (Jones and Osborne, 1985) but do appear interested in certain aspects of physics, particularly the practical experimental sessions (Jones, 1987). It has been found, in New Zealand as well as other countries, that senior secondary school students would appreciate more technological applications in the teaching of physics (Jones and Osborne, 1985; Jones, 1987; Linjse, 1986).

LEARNING THEORIES

This investigation lies within the constructivist tradition of science education research (Driver, 1982) and is based on the generative learning model of teaching and learning (Osborne and Wittrock, 1985). The main feature of this model is the generation of links between the selected input and those parts of the memory store considered relevant by the student. The learner will generate meanings which are consistent with existing knowledge, experiences, abilities, backgrounds and attitudes. New ideas may be integrated with existing ideas or be accommodated alongside.

Based on these and other assumptions of the model, a technological focus which is perceived by students as being relevant should enable the students both to attend to the learning situation (engagement) and to generate more adequately links between the new and existing ideas. The greater the number of links made, the more likely that a scientific idea will be remembered and will make sense to the learner.

THE INTRODUCTION OF TECHNOLOGICAL APPLICATIONS

Following extensive interviews, observations and surveys using accepted science education methodologies (for details see Jones 1987), a teaching method for introducing technological applications into senior school physics curricula has been developed. This has included the design, preparation and evaluation of teaching packages.

Some of the issues particularly taken in to account in developing these packages are detailed below:

(i) Classroom constraints

A major constraint in developing the classroom materials for New Zealand seventh forms (17-18 years) is the major national examinations held at the end of this academic year. Teachers felt concerned that the syllabus was already too large and there was not enough time available for the introduction of technological applications (Jones, 1987). Thus teaching packages had to develop concepts already required by the syllabus while not increasing the amount of time spent on the topic.

(ii) Selecting the technological application

For many parts of senior physics courses, students are likely to have very limited or no existing ideas about certain concepts that are involved. However by judicious choice it might be possible to identify technological applications which would enable students to generate cognitive links and thereby allow new ideas to become part of their long term memory.

Features desired in the material for introducing technological applications included:

1) Relevance in terms of human relationships and everyday life.
2) Relevance to the student's interests and existing knowledge with particular reference to gender differences. For example, it has been

found that girls preferred medical examples of technology whereas boys were more interested in technical aspects of devices (details in Jones, 1987).

3) A range of applications based on the same physical principle or concept. With individual differences in existing knowledge this will enhance the probability of each student generating a number of meaningful links.

4) Suitability for introduction at the beginning of the lesson with background material and the physics concepts directly accessible.

5) Availability of simple experiments that can be carried out to further explore and test students' ideas.

6) Development of a theme for the next few lessons so that new ideas can be related back to existing ideas, further reinforcing the physical concepts.

(iii) Structure of the teaching units

The chosen unit begins with the teacher introducing a theme or an actual technological device. The teaching sequence developed in this study is based on the key propositions of the generative learning model and on a desire to develop a more integrated knowledge structure of physics (Claxton, 1984).

The teaching sequence consists of five stages:

> ***Focusing stage****: This stage is designed to focus the students' attention on the learning situation. A context for learning is established in terms of a technological application, a social issue, etc, or an instance that relates to the students' existing knowledge. The teacher sets up a number of different situations so as to encourage the students to ask questions, put forward tentative statements, provide further information that they may have and discuss their ideas with other members of the class.*
>
> ***Exploration stage****: This is a time for the students to carry out investigations, to try to answer questions they may have and further explore their tentative statements. These further investigations may be experimental, demonstrations, reading exercises, group and class discussion of various issues, comprehension exercises, technological and theoretical problems. The students explore in more detail how devices work and the physical principles behind their operation. Historical and everyday aspects are also examined.*
>
> ***Reporting stage****: This involves students reporting back to the class the results of their investigations, discussing ideas and making summaries of the physical concepts involved.*
>
> ***Formalisation stage****: This is when the teacher and the students use the information gained in the previous stages to develop physics concepts and write them in a formal physics manner.*

***Application stage:** This may involve the student carrying out further investigations, attempting traditional school physics and other (technological) problems. This stage also includes other experimental, historical, philosophical, everyday and theoretical aspects of the physics concepts that have been developed.*

EXAMPLE OF A TEACHING UNIT: ELECTRICAL CAPACITANCE

This unit was designed to occupy the same amount of time as that allowed for in the current syllabus. The teaching package consists of a teacher's guide, student reading material, models of technological devices, photographic slides, student experimental kits and student experiments. Material was designed to be open-ended enough for the teacher to influence the presentation and student notes. The unit was constructed around three lesson formats (each of which uses the five stage teaching sequence outlined above but which emphasises three different physical concepts related to Electrical Capacitance).

(i) Lesson Type 1

The first type of lesson started with students examining a camera flash unit, including its internal structure (Focusing stage). Examination of the flash unit resulted in students asking questions and forming tentative ideas about camera flash units and capacitors. Next, students made models of camera flash units on circuit boards and were encouraged to explore and ask questions about the circuit and capacitors (Exploration stage). This activity gave them considerable time to test their own ideas and explore any further questions which arose out of their work. The concepts investigated were those of charging and discharging a capacitor, charge, voltage and energy. Following this the students were given the opportunity to pool their ideas and examine them for possible relationships (Reporting stage). At this stage a summary of individual and group ideas was made by the whole class. A series of formulae were developed from the students' own investigations and ideas (Formalisation stage). Numerical and technological problems were then attempted (Application stage).

(ii) Lesson Type 2

The second type of lesson structure involved associating a central theme (for example, detecting changes in our environment) with different technological applications. The students were able to choose an application that interested them and them study it in detail. Choices included medical, social and environmental issues. Examples included baby breathing monitors, altitude monitors and microphones (Focusing stage). Students carried out investigations (including experiments) and presented reports (class discussion, seminars, etc) to other class members (Exploration stage). The concepts explored were in relation to the construction of capacitors (area and distance between plates, series and parallel circuits) (Reporting stage). A series of formulae were also derived from the student's ideas under the guidance of the teacher (Formalisation stage). From these other technological applications were examined and typical school physics problems were attempted (Application stage).

(iii) Lesson Type 3

The third type of lesson was based on a social concern: the issue of cot deaths. After lengthy discussion by the whole class a baby breathing monitor was examined in detail (Focusing stage). Students then carried out investigations using circuit boards and explored various physical relationships including charging a capacitor through a resistor (Exploration stage). They then combined their ideas in a class summary and derived physical formulae (Reporting and Formalisation stage). Further applications and problems were investigated (Application stage).

EVALUATION OF ELECTRICAL CAPACITANCE UNIT

Evaluation of the teaching package involved three strategies. In the first the teacher was interviewed before, during and at the end of the unit. The second strategy involved talking to the students (30) during the lessons. A third evaluation analysis used a semantic differential scale (1 - 7) consisting of 16 bipolar adjectives developed by Osborne (1976) to evaluate new university courses (for example: Easy-Difficult, Interesting-Boring,...). Students completed the scale before (to record existing ideas about physics lessons) and after the unit and were then interviewed to explore their reasons for their responses. The emphasis of this evaluation technique was on the student comments rather than the statistical analysis of the responses. A summary of evaluation is given below.

Evaluation Strategy 1: Teacher Comments

The teacher reported:

1) Strong and sustained interest in the class.

> "I thought the approach was very good in a number of aspects. I firstly felt that the class was very interested in what was going on, particularly interested, and one group in particular were so enthusiastic that it was unreal. They are normally a pretty unruly sort of bunch ... incredibly on task and came up with all sorts of different ideas."

2) Greater student involvements.

"A typical student who found physics boring ... showed his interest by delivering a lot of answers and coming up with questions of his own."

3) Enhanced qualitative understanding.

"Increased grass roots understanding. They really have grasped the basics and weren't getting lost in a whole pile of formulae ... they were incredibly enthusiastic ... they came back with lots of ideas ... They were more enthusiastic about physics in general."

These views reinforced later when the students completed a standard test for this topic which had been used in previous years. The two 1986 classes involved in the trial had scored consistently lower in all previous tests compared to the 1985 class. However in the test on this trial capacitance unit, this year's classes scored higher than the 1985 class. When commenting on the results the teacher stated: "Those marks are really very good, possibly the best ever on that assignment".

4) Marked modification to teaching strategy.

"I think I am finding I can get along without getting into really gory derivation from Gauss' law or stored energy."

5) Increased learning in student experimental work

"I think they (students) get a lot out of it. It was good wandering around and hearing people discuss their ideas about capacitors."

Evaluation Strategy 2: Pupil reactions to the unit

Observations during the lessons indicated students became involved in the activities and were stimulated by them. For example in the first lesson where the camera flash unit was demonstrated, the students produced thirty questions and tentative statements about camera flash gun units and capacitors.

The students reported:

1) Interest in technological devices.

"You can understand the theory because it's more of a device used in the real world ... I did the thing on volcanoes ... it was good it showed the inverse thing between capacitance and the distance ... it was good finding I could do it."

"It's interesting seeing how physics can apply in everyday life and you can remember it better."

2) Links to everyday events.

"It was quite interesting because you can relate it back to something that you have seen happen or know something it's actually a real situation-rather than a theoretical thing ... you can relate it better."

3) Usefulness of topic.

"It's good learning practical uses. It's good finding it's so simple really ... Its use in society."

4) Links between technological and physical concepts.

"The apnoea mattress for hospitals ... we learnt how they work ... the resistance decreases and the capacitor charges more quickly ...

5) Support for the experimentally-based approach.

"I think it's good when you are not just told everything and you get a chance to figure it out for yourself as well."

6) Support for the choice provided.

"That are quite fun. You get to do your own thing."

7) Concern for traditional performance criteria.

"This is not going to help me get good marks."

Evaluation Strategy 3: Semantic differential probe

Students' comments, statistical analysis (t-test and sign test) and the semantic different probe (see Table) suggested that, compared with the usual style of teaching, the trial unit was considered to be significantly (1% level): (i) more interesting, (ii) easier and more straightforward with a technological bias, (iii) more enjoyable and relevant to everyday life (5% level), and (iv) less mathematical (1% level). The major factors involved in producing changed student responses appeared to be: (i) introducing technological applications that students considered interesting and could relate to, (ii) having the opportunity to pursue and individual investigation, (iii) finding out information for themselves, (iv) allowing class and group discussion, and (v) developing physical concepts from the applications, experiments and other investigations. Four of the thirty students did not react more positively to the unit. These students were already very successful in traditional lessons.

Table: Student responses to the capacitance unit using the semantic differential scales. (N=30)

Interesting: (25 more positive, 4 more negative)[2] **
"They were more to do with everyday life ...
like[3] the cot death machine ... it helps a lot.
"I found it more interesting because you had to think about it, not just given the information."

Easy: (27 more positive, 1 more negative) **
"I could actually picture it."
"It was the different way of approaching the problem."

Irrelevant to Career: (5 more positive, 21 more negative) **
"Physics in general is relevant but capacitors wouldn't come into it."

Relevant to Everyday life: (18 more positive, 4 more negative) **
"Emphasis on the uses of capacitance."

Enjoyable: (20 more positive, 4 more negative) *
"Enjoyable because of its relevance".
"I guess discussing it in class makes it better."
"It has been a fun time."

Straightforward: (20 more positive, 3 more negative) **
"There were not so many formulae ... in this case your basic knowledge brings out the formula so you can do it yourself."

Non-mathematical: (24 more positive, 3 more negative) **
"It was more thinking about it then trying to reach a formula."

Few Calculations: (25 more positive, 1 more negative) **
"They are still there but I did not find them as difficult."
"We sort of came up with the formulae ourselves."

Technological: (19 more positive, 1 more negative) **
"The applications of it were good ... if you do not know how it applies to things it is much harder to understand."

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1 More positive on the scale Boring-Interesting.
2 Only those students who response changed are recorded.
3 These comments are representative rather than idiosyncrasies.
** Significant at the 1% level using a two tailed t-test and a sign test.
* Significant at the 5% level.

CONCLUSIONS

A teaching unit, designed to improve links between physics concepts and students' existing knowledge, has been developed and evaluated. Based on key propositions of the generative learning model, attention gaining activities were introduced to facilitate new ideas being linked to relevant frameworks already held by the learner. Evaluation suggests that introducing an appropriate technological focus, combining activities and using a suitable teaching sequence generally enhance the learning of senior secondary school physics.

Student perceptions of the teaching unit were probably enhanced in part because the approach used was new and different. However, when a second teaching unit, based on the Doppler effect, was introduced to the class about four weeks later, very similar results were obtained with the same classes and other classes. The capacitance unit was also used in other schools with similar positive results from both teachers and students.

REFERENCES

CASIMIR, H.B.G. (1976). Education, Physics and Technology. Physics Education, 11, 11-15.

CLAXTON, G.L. (1984). Teaching and acquiring scientific knowledge. In Keen, T. and Pope, M. (Eds). Kelly in the Classroom. Educational Application of Personal Constraint Psychology. Montreal, Cybersystems.

DEPARTMENT OF EDUCATION (1972). Curriculum Development Unit Bulletin, No 58. Physics, University Entrance Teachers Guide. Wellington, N.Z.

DEPARTMENT OF EDUCATION (1973). Curriculum Development Unit Bulletin No 48. Bursaries/Scholarship Teachers Guide. Wellington, N.Z.

DOWDESWELL, W.H. (1979). Science and Technology in the Classroom. European Journal of Science Education, 1, 51-55.

DRIVER, R. (1982). Children's learning in science. Educational Analysis, 4, 69-79.

FENSHAM, P.J. (1985). Science for all. A reflective essay. Journal of Curriculum Studies, 17, 415-435.

JONES, A.T. & OSBORNE, R.J. (1985). Students' Perceptions of Physics in Society. Research and Development in Higher Education, 8, 348-354.

JONES, A.T. (1987). Classroom Perceptions of Physics and the Introduction of Technological Applications. D.Phil. Thesis, University of Waikato, New Zealand.

LAYTON, D. (1973a). *Science for the People*. London, George Allen.

LAYTON, D. (1973b). The Secondary School Curriculum and Science Education. *Physics Education*, *8*, 19-23.

LINJSE, P. (1986). Methods of promoting student motivation in physics education. Paper presented to International Conference on Trends in Physics Education. Japan.

OSBORNE, R.J. & WITTROCK, M. (1985). The generative learning model and its implications for science education. *Studies in Science Education*, *12*, 59-87.

OSBORNE, R.J. (1976). Using student attitudes to modify instruction in physics. *Journal of Research in Science Teaching*, *13*, 525-531.

Research in Science Education 1989, 19, 174 - 186

NEW APPROACHES TO THE INSERVICE EDUCATION IN SCIENCE AND TECHNOLOGY OF PRIMARY AND EARLY CHILDHOOD TEACHERS

(or MUM IS NOT DUMB AFTER ALL!)

Valda Kirkwood, Margaret Bearlin, Tim Hardy

INTRODUCTION

This paper reports preliminary research findings from an inservice program which is part of the Primary and Early Childhood Science and Technology Education Project (PECSTEP), based in the School of Education, University of Canberra (Note 1). PECSTEP has been funded by the A.C.T. Education and Training Council and the A.C.T. Department of Education, and is directed by Ms Margaret Bearlin and Dr Tim Hardy. This project builds on the work of the Women and Science Teacher Education Project (WASTE) (Bearlin, Annice and Elvin, 1988) which identified evidence that linking work in science with explicit treatment of gender issues in inservice programs can affect the attitude to science of women primary teachers, and the attitude of girls they teach. Because little similar work was being done at the preservice level, the WASTE Project Report recommended "research on the effect on the attitudes of women preservice teachers to science and science teaching, of teacher education courses in which work on gender and work in science are systematically linked or integrated with each other and with practice in schools which have wide affirmative action policies" (p 13). It soon became obvious, however, that such research at the preservice level would not be possible without companion inservice programs. PECSTEP was therefore designed to link the preservice education of teachers with appropriate practice in schools by providing a special inservice program for supervising teachers.

The approach to teaching and learning used in the project has been developed at the University of Waikato, Hamilton, N.Z. The Science Education Research Unit there (now the Science and Mathematics Education Research Centre) was directed initially by Dr Roger Osborne and has attracted the major part of the N.Z. Department of Education's research budget since 1978. The first three year project, Learning in Science Project (LISP), investigating teaching and learning of science in classrooms of 11 - 15 year olds, resulted in 56 working papers and many publications which are condensed in Osborne & Freyberg (1985). A second three year project LISP (Primary) followed and developed a way of teaching science in primary schools (an interactive teaching approach as outlined in Biddulph and Osborne, 1984) to take account of: a) the understandings about learning in science classrooms developed in the first project, b) the wariness of primary teachers to teach science, and c) a view of science as enabling children to make sense of the natural, and technological world in which they live. The project officer of PECSTEP during 1989 - Valda Kirkwood - had been project officer of the third LISP project which investigated the teaching and learning of the energy concept in science classrooms (Kirkwood 1988).

OVERVIEW OF PECSTEP

The purpose of PECSTEP is to improve teaching and learning in science and technology of girls and boys by increasing the number of early childhood and primary teachers who are effective educators. The project links the preservice education of teachers in science and technology with quality practice in schools by providing special inservice education for supervising teachers.

The project involves:

- the development, teaching and evaluation of a year length inservice program involving 70 primary and early childhood teachers in which each will develop a science and technology curriculum unit
- the modification, and evaluation of an existing semester length preservice unit in science and technology education for (approximately) 60 preservice teachers
- the establishment of regional support networks for the practising teachers taking the inservice program.
- the developing of curriculum modules able to be used in inservice and preservice teacher education programs All programs and units systematically link work on gender with the learning and teaching of science and technology.

THE INSERVICE PROGAM

The inservice program aims to increase the competence and self confidence of teachers in the science and technology areas by enabling teachers to:

- extend their understanding of children's learning in science and technology
- explore ways of assisting children with such learning.
- extend their understanding of the importance of and skills in science and technology in the lives of girls and boys
- extend their understanding of their own learning in science and technology
- extend their understanding of and skills in gender-inclusive science curriculum development and teaching
- develop further skills in teaching science and technology
- feel positive about teaching in this curriculum area
- supervise the work of preservice teachers in this curriculum area

The program consists of 14 two hour workshops in Semester 1, followed by class-based curriculum development in Semester 2. The program involves:

- participation in a science curriculum unit (toasters) based on interactive teaching-learning principles;
- exploration of the steps involved in the development of such a curriculum unit;
- development of another science curriculum unit (bread);
- development of another curriculum unit using their own class (in Semester 2).

During these workshops we focused on:

- the ideas, experiences, questions which teacher and children bring to lessons;
- the place of context in teachers' and children's learning;
- the different experiences and interests of teachers and girls and boys and the influence of these on their learning;
- ways of looking at technology, science, knowledge, teaching, learning and gender and their interrelationships.

Three groups of primary and early childhood teachers (70 of the 130 who initially expressed interest) are undertaking, in their own time, the year long inservice course. About one third of the teachers are either upgrading or doing a Masters course associated with the Project. Three participants are School of Education staff, nine have withdrawn during Semester 1, seven through over-commitment and two because the course was not meeting their needs.

The programme has involved teachers investigating their own questions about toasters (e.g. how does a toaster really work?) by taking toasters to bits, setting up electrical circuits etc. During these activities teachers have kept diaries to record steps in their own learnings and to reflect on the many questions - which have surfaced and been discussed - relating to their understanding of teaching, learning, science, technology, knowledge and classroom interactions.

A curriculum unit on bread began with a bread-making session which was followed by sessions in which teachers investigated their questions arising from the activity of baking bread. In addition there were focus sessions on gender issues, resources, understandings of science and technology, and of teaching and learning.

RESEARCH METHOD

Surveys

During the year three surveys will be completed; at the beginning of semester 1, the end of semester 1 and at the end of the year. These will help us find out where people start from in terms of their science background, their experience in science teaching and learning, and their ideas about and attitudes to science and technology, teaching and learning. The completion of these surveys is intended to initiate and provide reflective practice during the year as well as being an evaluative instrument.

The keeping of a diary

Throughout the year each teacher is keeping a diary to record:

- ideas, experiences of and questions about various aspects of science education encountered during the program
- suggestions and insights gained during the program which are personally significant for their learning and their children's learning, and for teaching
- reflections on the implementation of ideas gained in workshops in their own classroom
- a case study on a curriculum unit of their choice.

Evaluation Forms

An evaluation form was distributed at the end of semester 1. This asked teachers to comment on aspects of the course that worked (or didn't) for them, what they had learnt, what had facilitated that learning, and what impact (if any) the course had had on their lives.

Interviews

A smaller number of teachers (about 12) are being interviewed at least 3 times during the year to provide more in-depth data.

PRELIMINARY FINDINGS

A preliminary analysis of the evaluation form for Semester 1 of this inservice program indicates a number of aspects of the program highlighted by the participating teachers:

1. Teachers widened/altered their ideas about science and technology
2. Teachers widened/altered their ideas about teaching and learning
3. These changes in teachers' ideas/views were facilitated by a number of factors
4. These changes have led to other changes
5. The impact of the course has reached out beyond the teacher, the classroom, and the school.

The discussion now focusses on these aspects and are illustrated using teachers' comments (which are not idiosyncratic, but representative).

1. Teachers widened/altered their ideas about science and technology:

(a) Many overcame, their sometimes long standing, fear/awe of science and technology

> *I feel very excited about the way I reached and responded to this particular course, especially since I was always frightened of the word science, let alone what was involved in science. I almost had feelings of relief to think that I could actually learn about science, and for this subject to have meaning for me.* (Janelle)

(b) Others found science and technology could be fun.

> *I found I enjoyed more doing the unit on toasters perhaps because it gave more scope to find things out. As well it was an area which originally was taboo for me as I had never had the opportunity to do an in-depth study of a "toaster". The fun in doing such an activity was great.* (Emma)

(c) Some realised the "everydayness" of science and technology.

> *I liked the idea of using toasters and bread as subject matters, because before this course I tended to keep 'Science' in its own little box and indeed saw scientists as being shadowy figures in a research laboratory. These subjects brought home the practical uses of science and technology and just how much science and technology is related to my everyday life.* (Rhonda)

(d) Some focused on the philosophical aspects.

> *(I have learnt) - that science is a way of making sense of the world. (I have learnt) - that what we think are scientific facts are actually a consensus of what people at a particular time agree is the most probable reason for something happening, i.e. once people agreed that the world was flat, until enough people found evidence that led them to believe that it is actually round. Then it took a while before enough people thought it was round for that to become a consensus. Probably some people chose to believe it was flat still for hundreds of years after most people realized it was round.* (Wendy)

(e) Some became aware of a relationship between science and technology.

> *The toaster experiments opened my eyes in another way. In my diary I've written about my new "emerging awareness" of the relationship between science and technology. I'm not even aware why that relationship became apparent ... but I began to look at things differently. "Technology is not just machinery - it's changing things and the way they're used". I'd not thought about technology as being something "everyday".* (Pam)

(f) Some delved into particular aspects.

> *The most amazing aspect to me personally is coming to understand about electricity - its applications in the world around me; that it has sense and meaning in my world; that the table I touch and the chair I sit on is a chemical combination that ultimately is held together by electrical charges. This was a massive learning curve for me.* (Jacky)

2. Teachers widened/altered their ideas about teaching and learning:

(a) Some focused on their own learning.

I have increased my own science knowledge revived/revised some of the "dormant" concepts (dormant since the early 60's) - particularly related to chemistry. (Lorna)

(b) Some initiated on-going responsibility for their own learning.

I've learned an enormous number of things in a short time. I've learned a little bit of information about the actual content of what we did and that little bit is acting like a seed in my mind because I keep looking out everywhere for related information or incidents. I learned that one question can lead to an endless chain of questions, it's a self perpetuating process. I suppose its called curiosity. I only ever had this about people, relationships etc. but never about things. (Vivienne)

(c) Some related this learning to children's learning.

The teacher doesn't own the knowledge - we have to allow our students to construct and take responsibility for this knowledge in making better sense of our world. (Norma)

The idea of a "concept map" is very interesting and appealing ... as a way of establishing prior knowledge etc. (Felicity)

I now have more ideas on how to evaluate science, especially the inclusion of self-evaluation. (Jan)

Specifically I have gained scientific knowledge about toasters, bread yeast but in doing so I have learned to think more about providing resources and enabling the children to find resources to answer more of their questions during observation "perhaps have a more flexible environment in my room. (Heather)

The weekly meetings were great as far as stimulating enthusiasm but when we were working with toasters, I felt quite frustrated at having to leave the work we were doing, put it away for a week and come back to it "cold". I'm sure the children must experience this frustration when we compartmentalize our lessons like this also. (Pam)

(d) Some related their learning to their classroom teaching.

However, the important learning recorded in my diary is not only related to my own learning, it is related to what I have been able to take back to my classroom. Teaching is being a resource person, setting the scene for learning, encouraging children to ask their own questions, setting up a supportive learning environment, valuing everyone's thoughts.

> *Learning is a self-directed experience, a group process, sharing experiences and knowledge, questioning, exploring, discovering, making use of all resources, building on prior knowledge at own pace, making sense of the world. Science is interesting, everyday, relevant, fun, exploring, discovery and trying to make sense of the world. The fact that I have learned these things can only enhance my classroom practice and therefore, the learning of my children, I have learned these things through experience. If my experience within the course hadn't been positive, I would have had little to return to my students: As it is, they have gained and so have I.* (Judy)

(e) Some focused on the gender equity aspects.

> *More awareness of gender equity in the classroom across the curriculum. I'm conscious of my attitudes towards girls and boys all the time. I feel that in the past I have allowed boys to dominate areas like maths and science and now make more effort to be even handed to the point of sometimes giving girls preferential access to activities. During the term a GEAR programme has been operating and as a result of a preliminary survey, some science classes will be conducted as girls/boys only groups in an attempt to determine whether girls will participate more fully under these circumstances. This will operate with my team partner.* (Marlene)

(f) Some saw the ability to integrate science in other areas of their teaching.

> *I attended the course to get some new methods/ideas for science to get out of the rut of "experiments that don't work". I broadened my ideas of what 'science' is, can now fit science into a programme in a more integrated way.* (Betty)

(g) Some could relate the teaching/learning approach to other areas of the curriculum.

> *I can definitely see the value of the interactive teaching model in all subject areas. In a recent curriculum project on "LEGO TC logo", I used this teaching model as the 'ideal'. The planning, design and construction of a LEGO model in a group context involves all the suggested 'steps'. The inclusion of gears, wheels and cogs to be controlled by motors and finally by the computer is future technology in comprehensible action. In Maths activities, with the current emphasis on the use of concrete materials and problem solving, the approach would*

also be suitable. I feel very confident that my background knowledge is adequate enough for me to act as guide and facilitator in this subject. (Trish)

3. These changes in teachers' ideas/views were facilitated by:

(a) the atmosphere of the workshops.

The most important aspect of this course for me was the atmosphere that of acceptance, genuine interest in individuals, and a feeling of excited curiosity. The feeling that it was O.K to explore and investigate at our own pace in our own direction. The learning was real. I did not feel that I had to perform. I did not have to present a "beautiful picture" of something irrelevant and beyond my understanding. (Susan)

(b) "hands-on" approach.

The hands-on approach was wonderful, for although we provide experiences for children, we rarely have a chance to explore the 'unknown' ourselves. Exploration and careful observation were actively encouraged with tools, books, microscopes, batteries etc. any any resource needed being provided. (Lois)

(c) the learners (teachers) determining their own learning.

The way you taught - lectured really interested me - it is a technique I have used often with Grade One children but not with Kinder It is so good and yet I think we don't do it enough in the classroom. You let us, the students, control where we were going, what we wanted to do. Very powerful but confusing at first until you begin to think about the learning process. (Marion)

(d) the use of varying strategies.

(i) stating what you know at the beginning.

Having to state what I knew first. Clarified ideas and helped me know what I wanted to find out. (Jan)

(ii) concept maps.

In the specific areas of toasters and bread-making, and the science related to these, I can see by my concept maps just how much knowledge I have gained. This is a very simple, quick, but efficient way of highlighting understanding and knowledge before and after. (Jean)

(iii) reflecting (via diary and reportbacks).

I have found that the Reflective Thinking by us, as teachers, has helped *to re-investigate the thinking going on behind the teaching practice in classrooms. This can be extremely powerful. To encourage reflective learners we need to become reflective teachers. I want more time (for this).* (Marion)

(iv) groupwork.

Group interaction worked because I could try my ideas on others and hear theirs - ideas to investigate and ideas on how to find solutions. In my diary, I have recorded, "Groups valuable pooling of ideas, knowledge." Also, "Appreciation of group discussion, because all learn together. Did not feel uncomfortable." Reporting back worked because it raised further questions in my mind, and gave a broader overview than was possible in the smaller group situation. I discovered other aspects which were not areas I would have pursued. In my diary I have recorded, "Reporting back of other groups - more ideas, other ideas on how we could investigate." (Jan)

(v) modelling the process.

The most significant aspect of this course for me, was the modelling process which helped to develop a theory of learning which would underpin the teaching of science and technology. Course participants were given the opportunity to apply the theory to situations which enabled them to write their own curriculum. (Bill)

4. These changes in understandings have already led to other changes:

(a) Changes in confidence -

(i) their own knowledge.

This course increased my confidence in my own scientific knowledge. My previous background in science was chemistry and physics in high school and biology at teachers college. While my knowledge of, and interest in, biology was quite high I had "opted out" of physics and chemistry at high school as it had become very formalized. This course renewed the interest I had had in the early part of high school science. I feel much more confident now. (Ray)

(ii) taking part in discussions about science teaching.

I feel more qualified to talk about science teaching or at least offer an opinion in discussions. (Wendy)

(iii) teaching science and technology.

This course has been a unique experience for me in my many years in *educational institutions, and has given me confidence to give students the same kind of teaching and learning.* (Liz)

(iv) having experiences and understandings with colleagues.

I have felt much more confident about being Science Co-ordinator at school. (Lorna)

(b) changes in classroom practice.

(I am) being more at ease with letting the children in my class experiment, have a hands on approach. (Emma)

Process of forming questions to investigate I found most useful, for myself and particularly with the classes I teach. It has really enabled me to assess what the children already know and the level of their science thinking. Particularly useful also was the McLintock Coop. idea (and Susan Swan's Master's thesis) of the "Thinking Book" and which has provided a very useful vehicle for me to encourage children to look at their own learning and take more responsibility for it. They also love using this book and develop all sorts of other ideas (science-related) for using this book. (Lorna)

I have actually applied this model to the other curriculum areas as far as possible. I continue to be amazed and delighted at the amount of knowledge children have about topics which I myself have little knowledge about! I have also found that the children respond very positively and enthusiastically to this style of teaching. (Eva)

(c) changes within the school situation.

Since I started the course, there have been changes in the attitude towards science at our school. This has occurred through displaying our experiments in the corridor near the library; beginning a 'tinkers' club' in May. This club started out with a 20% membership of boys. I was surprised but delighted to see so many girls. At the commencement of 3rd term, a science room is being set up. Whilst I still feel a little insecure about passing on my knowledge to colleagues, I am finding that they regard me as someone who can help them with their problems about Science teaching. I'm also allowed to go on Science inservices. I say allowed because last year I wasn't allowed to go to the NASA inservice at the CCAE. Instead a teacher who was retiring in 6 months went. With the setting up of our Science room, attending inservices and curriculum meetings I find I am very busy, but also very satisfied. I feel I'm using my brain. (Rhonda)

6. The impact of this course has reached out beyond the teacher, the classroom and the school to:

(a) fixing things.

> *Confident to tackle other electrical appliances e.g. the iron, unable to fix washing machine - which I did fix.* (Barbara)

(b) other learning.

> *The use of an Interactive Approach facilitated my learnings. It's interesting to note that I was also enrolled in Intro. to Physical Sciences which gives a 6 week introduction to Physics and 5 weeks to Chemistry. This has been taught in a Traditional Science Method. The barriers I had/have to science were reinforced many times over. The work I did on electricity through 'Investigating Toasters' gave me the knowledge to understand what I was supposed to be doing in Physics.* (Jacky)

(c) trying new things.

> *My private life has also changed - I am now more confident to try new things, like different courses at night, - "I can learn about anything I want to" - and not feel silly about it.* (Janelle)

(d) helping their own children.

> *Thinking scientifically has also enabled me to help my daughter with her Year 9 Science and also with her maths. Now we look at something and say "What are we asked? What do we know? How can I use my information to solve my problem?"..... The best thing is that Mum is not dumb after all..*(Rhonda)

CONCLUSION

These preliminary findings have implications for the effective inservicing of early childhood and primary teachers in the science and technology areas. They are also likely to have implications for preservice courses. The research findings indicate that teachers can overcome their often negative views of science and of science teaching. Factors significant in this process appear to be : firstly, and most importantly, experience by the teachers of support and acceptance as they begin - often anxiously - their explorations of science, science teaching and learning.

Secondly, teachers begin their investigations in a context with which they are familiar, from the point "where they are at" and hence from which they can develop their investigations in directions they perceive to be the most fruitful. Thirdly, the sharing of explorations, reflections and progress amongst group members encourages the teachers to clarify and justify their own directions and perspectives, to learn of others' journeys, and to receive affirmation of their own learning. It is clear that this complex process cannot be hurried: inservicing teachers in an area that has been so neglected in the school curriculum requires an approach that fully recognises this .

Note

1 The University of Canberra (formerly the Canberra CAE) is a member of the Unified National System and is sponsored by Monash University.

REFERENCES

BEARLIN, M., ANNICE, C. and ELVIN, A. (1988) Women and Science Teacher Education. Report of a C.S.C. Project of National Significance.

BIDDULPH, F. and OSBORNE, R. (1984); Making Sense Of Our World. Hamilton: University of Waikato

KIRKWOOD, V. (1989) Teaching and Learning About the Energy Concept in NZ Secondary School Junior Science Classrooms. D.Phil.thesis, University of Waikato

OSBORNE, R. and FREYBERG, P. (1985) Learning in Science: the Implications of Children's Science. Auckland: Heinemann.

Research in Science Education 1989, 19, 187 - 197

GALILEO AND PENDULUM MOTION: A CASE FOR HISTORY AND PHILOSOPHY IN THE SCIENCE CLASSROOM

Michael R. Matthews

ABSTRACT

There are encouraging signs that the history and philosophy of science are becoming more important in the teaching of science and in the preparation of science teachers. This tendency is supported here by looking at the widespread treatment of Galileo's account of pendulum motion in science texts and classrooms, indicating that it is a less than adequate account of the historical facts, and suggesting that the teaching of this commonplace topic can be considerably enhanced if science teachers have some familiarity with basic research in the history and philosophy of science.

INTRODUCTION

There are encouraging signs that the history and philosophy of science are becoming more important in the teaching of high school science, and in the preparation of science teachers.

In the United Kingdom, the new National Science Curriculum includes topics in the history and philosophy of science. Eleven to thirteen year-olds will be expected to study the lives of one or more great scientists, and also the merits of some obsolete scientific theories as part of their normal science studies. Fourteen to sixteen year-olds will be expected to appreciate the clash and resolution of ideas so central to the growth of science; in addition British students will be required to have some conception of the rival philosophical views on the nature of science (NCC, 1988).

In America the AAAS Project 2061, the largest science education reform proposals since the Sputnik-inspired curriculum developments of the early 1960's, produced in 1989 a report, Science for All Americans, that recommends that the history and philosophy of science become part of all teacher training, and school science curricula (AAAS 1989). The Report selects six episodes in the history of science of outstanding significance for the development of western society, and requires that all students should know something of the intellectual and cultural contexts of these episodes. Concurrently the American National Science Foundation has funded two programmes, one for the introduction of history of science into schools, and one for the introduction of philosophy of science into school science courses.

The American National Science Foundation also supported an international conference on 'History, Philosophy and Science Teaching' that was held at Florida State University in November 1989. The science education journals, International Journal of Science Education and Science Education, devoted special issues to the papers being presented at the conference. Four other international journals also devoted special issues to the conference theme: Synthese, Educational Philosophy and Theory, Interchange, and Studies in Philosophy and Education. Over 300 scientists, teachers, philosophers, historians, and administrators from 15 countries attended the conference. The Proceedings are published by Florida State University Press (Gruender and Tobin 1989).

In Europe, the European Physics Society has conducted conferences in Rome (1980), Pavia (1983), and Cambridge (1990) on the theme of 'History of Science in Science Teaching' (Bevilacqua & Kennedy 1983, Thomsen 1986). Such historically based courses are taught in Denmark and Italy.

The Australian Federal Government's Discipline Review of Teacher Education in Mathematics and Science received submissions that Australian science teacher training would benefit from the inclusion of historical and philosophical material. The Report was submitted in late 1989.

All of the above developments argue that science teaching and learning needs to be more contextual, that science needs to be seen in its historical, philosophical, and intellectual context; that after stressing 'hands on science' we need to stress 'minds on science'.

In Britain the 'contextualist' position has been advocated since the reform proposals of Henry Armstrong at the turn of the century (Armstrong 1903). The British Association for Science Education in a 1963 report lamented that:

> Many [graduate science teachers] behave and think scientifically as a result of their training, but they lack an understanding of the basic nature and aims of science (ASE 1963, 13).

In a 1981 report the same Association described the teaching of science as a cultural activity as being:

> the more generalised pursuit of scientific knowledge and culture that takes account of the history, philosophy and social implications of scientific activities, and therefore leads to an understanding of the contribution science and technology make to society and the world of ideas (ASE 1981).

In Germany there has been a long contextualist tradition based upon the seminal writings of Ernst Mach in the late 19th century. Mach believed that the history of science is necessary for students to understand scientific concepts - what they refer to, and how they relate to other concepts (Matthews 1989).

The claims of this contextualist tradition are to be judged by its fruits - what illumination does the history and philosophy of science bring to the science classroom? In this paper pendulum motion is taken as an instance of a common-place science classroom topic that can be enhanced, and dealt with more engagingly, if the teacher has some knowledge of the philosophical and historical debates to which pendulum motion has given rise.

THE PENDULUM AND THE PROBLEM OF MOTION

In a letter of 1632, just ten years before his death, Galileo surveyed his achievements in physics and recorded his debt to the pendulum for enabling him to measure the time of free fall, which, he said

> we shall obtain from the marvellous property of the pendulum, which is that it makes all its vibrations, large or small, in equal times (Drake 1978, 399).

But much more than just a measure of time, the pendulum was central to Galileo's treatment of free fall, the motion of bodies though resisting media, the conservation of momentum, and the rate of fall of heavy and light bodies. In brief, it was central to his overthrow of Aristotelian physics.

Indeed the pendulum was important in the science of all of the physicists of the Scientific Revolution. Christian Huygens patented a pendulum clock in 1657 and used it not only for an accurate measure of time, but also to determine the gravitational constant g, to a remarkable degree of precision (32.22 ft/s2). Newton in his Principia used this determination to establish the linchpin of his theory of universal gravitation, namely that the centripetal acceleration of the moon towards the earth could be accurately predicted from the acceleration due to gravity on the surface of the earth.

Newton also used the pendulum to analyse wave motion, and subsequently to ascertain the speed of sound in air. He further used pendulum motion to dispute a major metaphysical claim of the Cartesians, namely the existence of the aether (Westfall 1980, 376).

THE TEXTBOOK STORY

Pendulum motion was clearly central to the development of Galileo's 'New Science'. What is less clear is how he came to the recognition and understanding of its isochronic motion. This point needs emphasis not just because of the psychological and epistemological issues involved, but also because of the Piaget-inspired movement in science education that takes the history of scientific development as a guide for the organisation and conduct of scientific pedagogy (Piaget 1970, 13). The history has first to be correct if pedagogy is to be usefully informed.

The standard physics text-book story of Galileo's discovery of the isochronic movement of the pendulum is that given by Fred Wolf. He says of Galileo that:

> When he was barely seventeen years old, he made a passive observation of a chandelier swinging like a pendulum in the church at Pisa where he grew up. He noticed that it swung in the gentle breeze coming through the half-opened church door. Bored with the sermon, he watched the chandelier carefully, then placed his fingertips on his wrist, and felt his pulse. He noticed an amazing thing ... Sometimes the chandelier swings widely and sometimes it hardly swings at all ... [yet] it made the same number of swings every sixty pulse beats (Wolf 1981, 33).

The Wolf story, minus the sermon comment, occurs on page 4 of the most widely used high school physics text in America, and one widely used in Australia - the Physical Science Study Committee's Physics (1960). It is meant to illustrate the essentials of the process of scientific observation and its interaction with technology. Is the core of the story - that Galileo came to, and justified, his account of isochronic motion of pendula by observation- correct? That is, did observation of a chandelier, or a pendulum, in some place, at some time, play the role in Galileo's science that the popular story suggests? Or is the story a scientific fable like the oft-told tale of Galileo dropping weights from the Leaning Tower of Pisa in order to discover the law of free fall?

The year referred to by Wolf is 1581, Galileo being born in 1564. Alexandre Koyre tells us that at that time the cathedral of Pisa had no chandelier (Koyre 1968, 96). This is a small detail, and there were of course other cathedrals, and other chandeliers that Galileo could have observed.

ARCHIMEDES' INFLUENCE ON GALILEO

Prima facie there has to be something wrong with the text-book story about the discovery of isochronic motion of the pendulum, there has to be something missing in the tale. Measuring time in a reliable manner was a long sought-after goal. Ecclesiastical needs, the urgency of calendar reform, the problem of determining longitude at sea, and everyday commercial requirements - all of these provided incentive for the discovery of a reliable time-piece. In the two thousand years since the detailed scientific observations of Aristotle, the world had countless thousands of acute observers, and dedicated natural philosophers. The medieval physicists were extremely sophisticated. All of them would have had the opportunity to see swinging lamps, tension weights on instruments, and comparable pendulums. That Galileo should be able to just open his eyes and see the isochrony of pendulum motion when all before him who had made use of pendulums, including Oresme, Buridan, Benedetti, and Leonardo da Vinci, failed to do so, is most remarkable.

What is missing from the popular tale is the emphasis that Galileo placed upon mathematical, specifically geometrical, analysis in science. His proofs for the isochrony of the pendulum derived more from geometry than they did from watching chandeliers during boring sermons. This mathematising of science arose from his adoption of the Archimedean method in physics.

Galileo was appointed to a lectureship in mathematics at the University of Pisa in 1588. He quickly became enthralled with the mathematics and mechanics of the 'Superhuman Archimedes', whose name Galileo never mentioned 'without a feeling of awe' (Galileo 1590, 67). Archimedes above all utilized Euclidean geometry in the service of mechanics; he gave geometrical solutions to practical problems concerning common machines such as the lever, pulley, wheel and axle, wedge, and screw. Galileo was one of hundreds of other Renaissance scientists who followed in the mathematico-physical footsteps of Archimedes whose works had been translated in the mid and late 1500's.
Galileo's major Pisan work is his On Motion (1590). In it he deals with the

agenda of problems currently being discussed in the scholarly academies - free fall motion in a straight line, motion on balances, motion on inclined planes, and circular motions. In all of his treatments the physical circumstances are depicted geometrically, and mathematical reasoning is used to establish various conclusions. There is as yet, and Galileo is 25 years of age, no mention of the observation of isochronic pendulum motion. Galileo's genius was to see that all of the above motions could be subsumed and dealt with in one argument, and one diagram. He later saw that this diagram represented the geometrical depiction of idealised pendulum motion.

In chapter 14 of On Motion Galileo addresses the problem of 'why the same heavy body, moving downward in natural motion over various planes ... moves more readily and swiftly on those planes that make angles nearer a right angle with the horizon'. He depicts this situation as indicated here, and goes on to ask 'We must find furthermore, how much faster the body descends on BA that on BD, and how much faster on BD than on BE'.

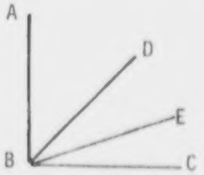

FIG 1.

Galileo then said that in order to answer these questions we must first take into consideration that a 'heavy body tends to move downwards with as much force as is necessary to lift it up', the problem then becomes 'if we can then find how much greater force is needed to draw the body upward on line BD than on line BE, we will then have found with how much greater force the body will descend on BD than on BE'. To answer this question Galileo then asked the reader to

'consider a balance CD, with center A, having at point C a weight equal to another weight at point D. Now, if we suppose that line AD moves toward B, pivoting about the fixed point A, then the descent of the body

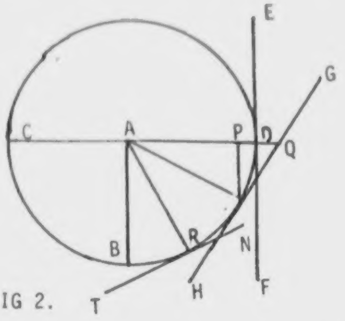

FIG 2.

at the initial point D, will be as if on the line EF.'He goes on 'If, then, we can show that the body is less heavy at point S than at point D, clearly its motion on line GH will be slower than on EF.' By utilizing the theory of moments, Galileo concludes that

> Therefore the speed on EF will bear to the speed on GH the same ratio as line DA to line PA ...Consequently the same heavy body will descend vertically with greater force than on an inclined plane in proportion as the length of the descent on the incline is greater than the vertical fall (Galileo 1590, 64).

Galileo adds a most significant rider to the above proof. He says that

> But this proof must be understood on the assumption that there is no accidental resistance (occasioned by roughness of the moving body or of the inclined plane, or by the shape of the body). We must assume that the plane is, so to speak, incorporeal or, at least, that it is very carefully smoothed and perfectly hard. ... and that the moving body must be perfectly smooth, ... and of the hardest material.

He has here introduced crucial idealizing conditions. These are the conditions that will bring him into conflict with the greatest mechanician of his age, Guidobaldo del Monte, and they are also the conditions that begin to define the difference between the old science of Aristotle, and the new science of Galileo and the Scientific Revolution.

If we look at the above diagram we can see that it will also represent a pendulum suspended at A, having a length AD, and a bob which moves through D, S, R, B

PENDULUM MOTION

Guidobaldo del Monte was one of the great mathematicians of the sixteenth century, he was a patron of Galileo, and also shared the ages' enthusiasm for Archimedes. (See the Drake translation of his Mechanics in Drake and Drabkin 1969.) In 1602 Galileo wrote to him of descent along a circular arc, the circumstance of the pendulum. In the letter Galileo outlined his theorem that 'the time of descent along any chord of a vertical circle to its lowest point remains the same, regardless of the length and slope of the plane.' He elaborated this to include the conjecture that descents along arcs of the lowest quadrant should be completed in the same time regardless of the length of the arc (Drake 1978, 68). This was the situation of the isochronic pendulum.

Galileo's proof of this theorem proceeded as follows.

Let BA be the diameter of circle BDA erect to the horizontal, and from point A out to the circumference draw any lines AF, AE, AD, and AC. I show that equal moveables fall in equal times, whether along the vertical BA or through the inclined planes along lines CA, DA, EA, and FA. Thus leaving at the same moment from points B, C, D, E, and F, they arrive at the same moment at terminus A; and line FA may be as short as you please.

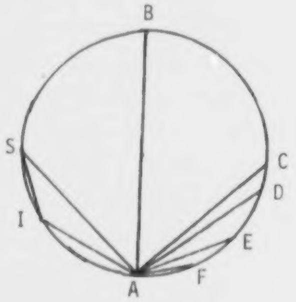

FIG 3.

This is close to a proof for isochronism, but not quite. He says to Guidabaldo 'But I cannot manage to demonstrate that arcs SIA and IA are passed in equal times, which is what I am seeking' (Drake 1978, 71). There is no mention of swinging chandeliers and pulse-beats. However he does allude to the pendulum situation and says that two six feet pendulums, hung by slender threads, are synchronised through 1000 swings, one being displaced widely, the other barely displaced from vertical. This is already an experimental situation, seemingly inspired by the mathematical depictions of On Motion. Even so it is not thought of as a demonstration, this has to be a mathematical proof.

Del Monte was not impressed by these proofs, claiming that Galileo was a better mathematician than a physicist. He reasonably could not believe that one body would move through an arc of 100 miles in the same time as another, suspended by the same length of rope, would move only one inch. Further as a mechanic he conducted experiments on balls rolling within iron hoops and found that Galileo's claims were indeed false.

Galileo stuck to his story. In his final great work in mechanics, Discourse Concerning Two New Sciences (1638), where he proposes a 'new science of a very old subject', Galileo says that

> It must be remarked that one pendulum passes through its arcs of 180, 160 etc in the same time as the other swings through its 10, 8, degrees. ... If two people start to count the vibrations, the one the large, the other the small, they will discover that after counting tens and even hundreds they will not differ by a single vibration, not even by a fraction of one (Galileo 1638, 254).

Wolf, the PSSC authors, and most science text-book writers who make mention of the subject suggest that any old (or young) observer who, at the time, cared to open his eyes would see what Galileo saw. Not so. Del Monte did not see it. As early as 1636 the notable physicist Mersenne had reproduced Galileo's experiments and not only agreed with del Monte, but doubted whether Galileo had ever conducted the experiments (Koyre 1968, 113-117). Within two decades of the publication of the New Sciences Huygens had shown that Galileo's isochronism claims were, strictly speaking, false. Not only the empirical evidence, but also a large and influential part of the scientific community opposed Galileo's claims about isochronism. Modern researchers have duplicated the experimental conditions described by Galileo and have indeed found that they do not give the results that Galileo claimed (Ariotti 1968; Naylor 1976).

Del Monte and the rest never tired of pointing out that actual pendulums do not behave as Galileo maintained. Galileo never tired of saying that ideal pendulums would obey the mathematically derived rules. Del Monte retorted that physics was to be about this world not some other mathematical world. Galileo strove to make this world conform to the mathematically depicted world, he refined experiments so that the experimental situation ever more closely embodied the ideal. But his theory was deficient, so even in the ideal, his pendulums were not going to be isochronic. The theory was perfected by Huygens, and later by Newton. Their cycloidal pendulums, of long lengths, swinging through small arcs, would be closer to the isochronic pendulum that supported so much of Galileo's new science.

Galileo's debate with del Monte demonstrates the difference between the old Aristotelian, empirical science, and the new mathematical, theoretical, experimental science of the Scientific Revolution. We can see in the debate the embryonic distinction between real and theoretical objects of science, also the scientific preference for imposing truths on the world, rather than just letting the world speak in its own messy way. As Nancy Cartwright has said for the laws of physics to be useful they have to lie (Cartwright 1983). Some of this momentous development can be conveyed to students in high school and primary school treatments of pendulum motion, but not if the comfortable myths of our age are preferred to the exciting and challenging struggles of scientific history.

Pendulum motion is rightfully a common topic in school science programmes. Most pendulum experiments do not work the way the textbook suggests. The standard response is to ignore what happens and to write up what the text says. If teachers are familiar with the history and philosophy of science there are more engaging alternatives available - a story about how del Monte got the same results that the students got, and the way in which the famous Galileo kept urging him to consider not the actual results but the ideal results. The student might then reasonably ask whether science is telling us about the real world, or about some ideal world. That can be the beginning of another interesting discussion.

REFERENCES

American Association for the Advancement of Science, (1989). Science for all Americans. Washington, AAAS.

ARMSTRONG, H.E. (1903). The teaching of scientific method. London, Macmillan.

ARIOTTI, P. (1968). Galileo on the isochrony of the pendulum. Isis,59, 414-426.

Association for Science Education. (1963). The training of graduate science teachers. Hatfield, ASE.

Association for Science Education. (1981). Education through science. Hatfield, ASE.

BEDINI, S.A. (1986). Galileo and scientific instrumentation, in W.A. Wallace ed. Reinterpreting Galileo. Washington, Catholic University Press, 127-154.

BEVILACQUA, F. & KENNEDY, P.J. eds. (1983). Using history of physics in innovatory physics education. Proceedings of an international conference, Pavia, Universita di Pavia.

CARTWRIGHT, N. (1983). How the laws of physics lie. Oxford, Claredon Press.

CLAGGETT, M. (1959). The science of mechanics in the middle ages. Madison, University of Wisconsin Press.

DRAKE, S. ed. (1957). Discoveries and opinions of Galileo. New York, Doubleday.

DRAKE, S. (1978). Galileo at work. Chicago, University of Chicago Press.

DRAKE, S. and DRABKIN, I.E. eds. (1960). Mechanics in sixteenth-century Italy. Madison, University of Wisconsin Press.

GALILEO, GALILEI (1590). On motion, translated by I.E. Drabkin and S. Drake, Madison, University of Wisconsin Press, 1960.

GALILEO, GALILEI (1638). Dialogue concerning two new sciences, translated by H. Crew and A. de Salvio, New York, Dover Publications.

KOYRE, A. (1968). Metaphysics and measurement. Cambridge MA, Harvard University Press.

MATTHEWS, M.R. (1988). A role for history and philosophy in science teaching. Educational Philosophy and Theory, 20, 67-81.

MATTHEWS, M.R. (1989). Ernst Mach and thought experiments in science education. Research in Science Teaching.

National Curriculum Council. (1988). Science in the national curriculum. London, NCC.

THOMSEN, P.V. ed. (1986). Science education and the history of physics. Proceedings of an international conference. Aarhus Denmark, University of Aarhus.

WOLF, F.A. (1981). Taking the quantum leap. New York, Harper and Row.

Research in Science Education 1989, 19, 198 - 209

THE INFLUENCE OF CLASS DYNAMICS ON INDIVIDUAL LEARNING

Ian Mitchell

BACKGROUND

In 1985 a group of teachers and academics set up the Project for Enhancing Effective Learning (PEEL) at Laverton High School. This was a cross-faculty action-research project which aimed to teach students how to learn more metacognitively (Baird and Mitchell 1986). A range of changes in students' learning behaviour were hoped for. For instance, it was hoped that students would routinely ask themselves a range of self-questions such as "What do I think about this?", "Is my view different from other peoples' views?", "What other situations should this be relevant to?", "Can I think of a situation where this explanation does not seem to work?" These self-questions were expected to often result in new classroom behaviours; among other things, students would be encouraged and trained to offer and justify alternative opinions, to suggest new activities and to seek links between the content of the lesson and other lessons, other subjects and the outside world. Changes such as these should significantly alter the class dynamics in a number of ways.

This paper reports on attempts to discover if PEEL does change class dynamics and if so, how; what effects does this have on individual learning. The nature of the study has led me to choose to report it in the first person.

In 1987 and 1988 I had two Year 10 Science classes which had had a number of PEEL teachers over several years. I had taught one of them (10A) for four years and the other (10D) for two. I had a third Year 10 class in 1988 (10E) which had had significantly fewer PEEL teachers and had had a very traditional Science teacher in Year 9. Data was collected from these classes throughout their Year 10 year. Students were studied particularly intensively during a Mechanics unit which incorporates a large number of PEEL strategies. Data sources included audiotapes, student and teacher diaries, other written feedback from the students, clinical interviews (by a third person) and the records of an outsider who observed some lessons.

WHAT WERE THE CLASS DYNAMICS?

My global impression was that the dynamics of 10A and 10D in Science were excellent and very different to many other classes. The atmosphere was consistently warm, trusting, co-operative, collaborative, participatory, and intellectually active; discipline problems never arose. These dynamics were highly resistant to short-term influences such as weather, the time of day, disruptive events outside the classroom, etc. 10E were very different; the lesson quality fluctuated wildly (much more than normal) with short-term influences, especially the time of day. Their good lessons were very good in many ways. 10E did not represent a completely traditional class, but I still felt the class dynamics never reached the levels of the other two classes. These impressions, if accurate, would support the conclusion that PEEL did improve class dynamics and that this improvement continued over several years. My problem was how to justify this. The difficulties of reporting this type of research is one theme of this paper. A study of the learning, teaching and dynamics of a whole class has the advantage of being very naturalistic. It is more likely to produce findings which are directly relevant to real classrooms than research which has a narrower focus and a tighter control over more variables. The sources of "error" and "noise" in the latter style research are often important aspects to be studied in the former style. However, there are disadvantages - the researcher tends to be swamped with data. Reflecting on this data may well lead to the formation of a range of inferences and insights but it can be difficult to organize and report on what occurred in ways which allow others to evaluate the validity of the findings.

What follows is a description of the development of one attempt to solve this problem. Since totally non-PEEL classes do not exist at Laverton I decided as a first check to carry out an Interaction Analysis (Amidon and Flanders 1963) on tapes of several 10A lessons and compare these with some data collected by Theobald (1978). During 1975 Theobald studied the Year 11 biology classes of four teachers who were selected to represent a range of teaching styles prevalent at the time. An interaction analyst classifies the nature of the teacher-student interaction at fixed, short time intervals throughout a lesson. The classes Theobald studied will be referred to as the '75 classes.

There are several uncontrolled variables in comparing these classes with mine and I did not intend to draw inferences from anything other than gross differences between them.

Since many of the desired changes of PEEL involve student talk, I initially compared the percentage of total class time spent in student talk between the '75 classes (23%) and 10A (31%). This change is not large and may not be significant, it certainly does not reflect the differences I felt existed. I then looked at what type of student talk was occurring. Theobald had classified student talk as either Initiating or Responding. Measured as a percentage of total student talk, 10A did show significantly more Initiation (68%) than the '75 classes (44%). What were they talking about? Theobald had classified talk as either about Content or about Management (which included raising procedural issues such as "How do I do this task?"). The difference here was very substantial - 49% of the total student talk in the '75 classes was about content whereas the figure was 88% for 10A. Measured as a percentage of total class time, student initiated talk about content averaged 18% for 10A and below 5% for the '75 classes. In the description of Interaction Analysis by Amidon and Flanders (1963), student initiated talk about the content does not even appear as a possible category, hence 10A's progress in this area does appear substantial.

A sample of lessons from 10E showed that they had a lower proportion of student talk (20%) a similarly high proportion of student talk on content (92%) rather than on management and an even higher proportion of initiating (79%) rather than responding. The proportion of total time which was student initiated talk about content was 15%. These figures confirmed that 10E had also made progress, however they did not reflect what I felt was a significant difference in quality between the 10A and the 10E class dynamics. There were several aspects about 10A which I felt were "better." One was the very erratic nature of the 10E dynamics, this will be discussed shortly. A second was that while a number of 10E students would contribute useful ideas and questions, they were much more dependent on me to produce the "right" answer. A third was that I felt there was a generally broader level of class involvement with 10A (and 10D). Once again my problem was how to justify these last two assertions.

One outcome of the reflection by PEEL teachers on their practice has been a list of some specific behaviours which we were looking for in the classroom -several of these were listed on page 198. All three classes regularly displayed many of these behaviours but, as Table 1 shows, 10A and 10D displayed them more often and had far fewer students who (over 5 lessons) did not display any. This data supported my belief that very few students in

10A and 10D had no commitment to the lessons, but 10E contained a significant group who were likely to be uncommitted.

Table 1 : Pattern of Good Learning Behaviours (G.L.B.'s)

	Number of students who display G.L.B.s over 5 lessons							
	Number of Good Learning Behaviours							
Form	0	1-2	3-7	8-12	13-15	18-27	>28	*Total Number of G.L.B.s*
10A (n=23)	2	5	5	3	2	2	4	253
10D (n=23)	4	4	5	3	2	3	3	230
10E (n=23)	10	3	5	2	1	2	-	135

Although the pattern of 10E lessons clearly contains a quite reasonable level of intellectual activity (i.e., clear progress had been made), I felt 10A were much better at listening to each others' comments and questions and hence following an issue through or developing a major new idea. To verify this opinion I decided to try a different analysis by recording (as a percentage of total talk) the proportion of student comments which were responding to an idea or question raised by another student as distinct from either responding to something said by the teacher or raising a quite new issue. Over a sample of four lessons there was a substantial difference between 10E (2.7%) and 10A (11.4%).

WHAT WERE THE EFFECTS OF THE CLASS DYNAMICS?

The above data indicates that the global impressions mentioned earlier had some basis. What effects did this have on the learning of individual students? Theories of learning often consider the learner to be an individual interacting with a teacher and/or instructional materials. Grafted onto this is the common knowledge that peer group interactions are an important influence on a student's general willingness to work. I would argue that the learner needs to be seen as a member of a class and the dynamics of that class will usually have a significant influence not only on his or her level of involvement, but also on the way the student learns, and on their beliefs about teaching and learning.

Effect on the Inclincation to Contribute

A number of interview comments from both 10A and 10D supported the assertion that students are much more likely to get involved and contribute to class discussion when there is a high level of involvement. "When there's a good discussion and everybody's having a say then I will too" was a typical comment. The PEEL strategies have been strongly influenced by Barnes's views about the central role of language in learning (Barnes 1976). If one supports these views, then the powerful influence of the class dynamics on individual learners willingness to participate and contribute is seen as a significant influence on each individual's learning. This is particularly true during fluid, loosely structured and highly interactive lessons which are a common outcome of PEEL. In these lessons each student's learning is dependent on all the others. Only a very few students have been found who, in these sorts of lessons, can divorce their own learning from a low level of involvement by the rest of the class.

Effects on the Type of Good Learning Behaviours Exhibited

Not only do good class dynamics encourage students to contribute more often, they also change the type of learning behaviours students exhibit and hence change the way individuals are learning. Laverton is near a large Air Force base and there is a steady turnover of students. At the start of, and during 1987 and 1988, both 10A and 10D had several new students arrive. Invariably they were initially non-plussed by the class dynamics and exhibited some very different learning behaviours. They would seek (in order to memorize) simplistic answers to complex questions, they could not (and would not) reflect on their own views, they would not search for weaknesses in the teacher's explanations, seek reasons and purposes, suggest new activities, etc. These are major changes; we have found that for a whole class they usually require more than one year. However, when new students entered a class already displaying these behaviours they would change much more quickly - some substantial changes occurred in a few months. The other students were acting as role models for the new students, obviously the new students were influenced by how the teacher dealt with them, but they were also influenced by watching how the teacher reacted to other students' comments.

Effects on Beliefs About Teaching and Learning

As we reported earlier in the project (e.g. Baird and Mitchell 1976) achieving student change during the first year of PEEL was particularly difficult because the students had strongly held conceptions of, and attitudes to learning which were in direct conflict with the goals of the project. Students strongly rejected such activities as discussing, using speculative language, and considering "wrong" answers; they demanded written notes containing "right" answers. The interview (and other) data from 10A and 10D provides good evidence of a very substantial shift by most students - only a very few of the students who had been in the class for some time said they would prefer to be told right answers and most strongly endorsed the need for fluid lessons. Comments such as "I think it is good to get us confused and then to clear the air", "I predicted wrongly, so I learnt something" would not have been made in 1985. A number of students expressed this support in terms of the whole class; "*we* like class discussion", "*Our class* is good at discussion" were typical comments. A number of students in 10A and 10D were very positive about the value of *other* students' comments for *their* learning; "They are useful because you think one thing and then they say something else, it may make you change your mind". "They help you sort out your own ideas, but you have to listen". This is testimony to the value of good class dynamics.

These changes are certainly due, at least in part, to the long period of contact with PEEL teachers which 10A and 10D students had. To gain some further insight into how much they were also due to the class dynamics it is worth contrasting the 10E students and the *new* students in 10A and 10D: they had an exposure to PEEL teachers which was roughly comparable. In 10A and 10D there were 28 students who had been in the class for two years or longer, twelve who had joined at the start of Year 10, and 6 who came in during the Year 10 year. The students who came in during the year showed (in interviews and class behaviour) a considerable variation in their conceptions of learning which correlated closely with the length of time they had been in the class. The ones who had only been present for a few weeks recognized a clear difference in the class dynamics but had very little understanding of it, two students who had been present for longer (about 3 months) showed a clearer understanding of some aspects but not others. The students who had been present from the start of the year had made most progress in this area but differences could still sometimes be seen between them and the students who had been in the class for longer. As might be expected, changes in attitudes were slower than changes in conceptions. Only one of the six newest students showed any support for what we were doing, and this was uneven: she enjoyed discussion and question asking but was irritated by my delayed judgement - she wanted answers. The twelve students who were new at the start of the year varied but overall were more supportive; most of them were definite in their support for most of what we were doing however some reservations were expressed, several students stated that they had changed their opinions (to more positive ones) during the year. The 10E students showed much less development in both conceptions and attitudes. Only a few of them understood the possible purposes of discussion, delayed judgement and question asking and only four students expressed support for these activities.

One needs to be careful in interpreting interview data, but these results would support two conclusions. Firstly, that changes in conceptions of learning are necessary before changes in attitudes can occur; one needs to be able to imagine something in order to be able to support it. Secondly, good class dynamics are very helpful in changing students' conceptions of learning and probably their attitudes as well. One needs to regularly see alternative learning behaviours working successfully in order to understand them.

Resistance to Short Term Influences

As mentioned earlier, 10A and 10D were highly resistant to the short term influences which can so often destroy a good lesson. The students got into a routine of active learning and rarely broke this. One of the sources of data was student journals in which the students were asked to describe each science lesson and their reactions to it to an outsider. I had asked them to record (without revealing personal secrets) if their general mood had been affected by an outside event. Understandably, only a few such instances were recorded, but there were four cases where a student reported and s/he entered the classroom upset, or angry or distracted, but did not try and interfere with the lesson because it was obvious to them that the rest of the class wanted to get on with it.

HOW DO YOU GET GOOD CLASS DYNAMICS, WHAT AFFECTS THEM?

Just as government in a democracy can only occur with the consent of the governed, so good learning can only occur with the consent of the learner. In a highly structured lesson, where the tasks are more routine, a teacher can mandate working; "Get on with your work!" is a sensible command. However, one cannot mandate high order intellectual activity such as reflecting on and contributing one's own ideas. Behaviours such as these will only be exhibited if the student understands and supports their purpose. Hence changes in conceptions and attitudes are absolutely essential.

Several related, but different, changes are necessary. Each has a somewhat different effect on the class dynamics. For instance, the students need to understand and support the value of putting up new ideas and asking reflective questions. This change may be easier to generate than the next three, it was the only one which was widespread among the 10E and new students. Students also need to understand and support the value of arguing an idea through, of listening to and reacting to other students' contributions, and the role of and need for intellectual stress and confusion during a unit. A number of 10D students were interviewed at a point of high (and deliberate) confusion - I had made them aware that there were a range of conflicting explanations in the class and that many of their own beliefs about forces and movement did not explain some situations. These 10D students recognized that they were confused, but they had experienced this before, understood the need for it and expressed a lot of confidence that it would eventually be resolved.

As I mentioned earlier, not only were 10A and 10D unusually consistent in their behaviour, 10E were unusually erratic. When analysing the audiotapes of good and poor lessons with 10E one key factor emerged; the amount of what I shall call "bushfire time". By this I mean time when the teacher is forced to abandon what s/he was intending to do to deal with management issues or an interruption (such as a visitor). It does not include time spent on classroom organization or administration which was planned for. With very fluid lessons the amount of bushfire time appears to be critical and to render such lessons unstable towards either clear success or clear failure. One typical scenario, which is illustrated by Figure 1 goes like this.

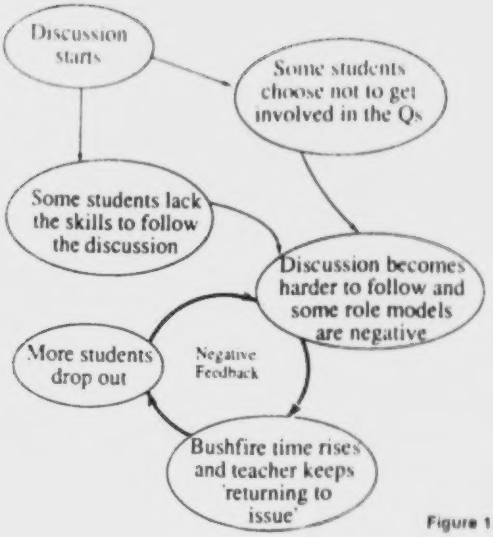
Discussion starts
Some students choose not to get involved in the Qs
Some students lack the skills to follow the discussion
Discussion becomes harder to follow and some role models are negative
More students drop out
Negative Feedback
Bushfire time rises and teacher keeps 'returning to issue'

Figure 1. Effect of high bushfire time

A discussion begins with some students participating however some others don't understand or are not interested in the question(s). These students begin off-task activities and the teacher has to halt the discussion to deal with them ("bushfire time"). The teacher then tries to "return to the issue" however this interruption has made the discussion harder to follow (more sustained concentration is required), moreover, off-task activity is being role modelled. A few more students drop off, bushfire time increases, the discussion becomes even harder to follow and so on. This cycle provides strong negative feedback and the lesson fails. However, another scenario is possible; which is illustrated in Figure 2.

The discussion begins and, for several possible reasons, some key students get initially involved who thus role model active participation. The low (or zero) bushfire time means the discussion remains coherent and easier to follow, more students get involved, there is a general atmosphere of active learning, the discussion remains easy to follow, more students contribute and we now have a cycle providing strong positive feedback. This model is obviously somewhat simplistic but in seven successive 10E classes the bushfire time was either over 25% of the total class time or under 2%. With 10A it was generally zero and never exceeded 1%.

Another reason for the difference between 10A, 10D and 10E was the need for the students to develop a series of trusts. They need to trust the teacher in several ways. They need to trust him or her to be supportive of their views and not to react disparagingly to incorrect comments. This trust appears to be relatively easy to generate. It was strongly held by all the students interviewed. The students also need to trust the teacher to eventually deal with all (or most) issues and questions. This is crucial to good class dynamics. 10E students did not have this trust - they tended to be aggressively demanding that I deal with their question now - the "squeaky wheel gets the grease". A third trust that clearly takes some time to develop is that confusion will be temporary - resolution will eventually occur and the confusion will have led to better learning. Students must experience complete units to begin to develop this trust. Finally they need to trust the other students to be supportive, and not disparaging. This is assisted by overt intervention by the teacher to make clear the discussion behaviours expected.

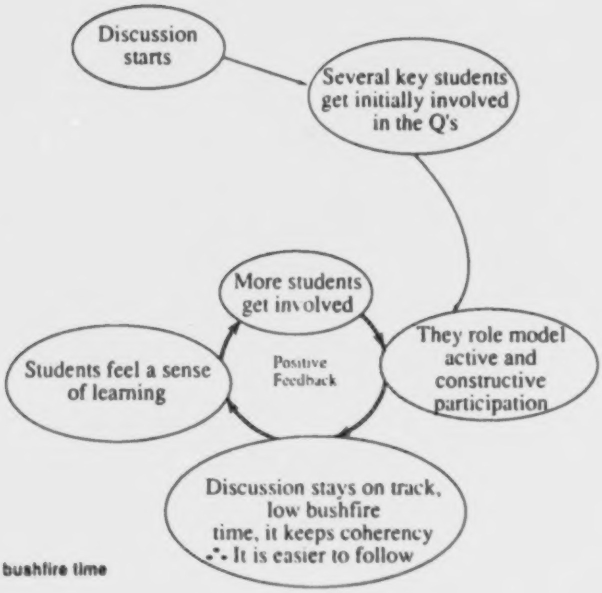
Discussion starts
Several key students get initially involved in the Q's
More students get involved
They role model active and constructive participation
Positive Feedback
Discussion stays on track, low bushfire time, it keeps coherency ∴ It is easier to follow
Students feel a sense of learning

Figure 2. Effect of low bushfire time

As stated at the outset, the reason for this research dealing with whole classes (rather than selected individuals) is to make the findings as transferrable as possible to normal classrooms. Generating each of the understandings and trusts listed above requires related, but different actions by teachers. Planning a long term strategy is made more purposeful if one is aware of the likely barriers to change. For instance it is very useful after a unit has been completed to review what occurred, to remind the students of the fact that their initial confusion was resolved, and to discuss with them the value to generating intellectual conflict.

Finally, there are two administrative implications of these findings. Firstly there are strong arguments for keeping a group of students intact and not reshuffling classes at the end of each year. This is common, but it is not so common for teachers to take classes for successive years. My experiences with both 10A and 10D have convinced me of the power of taking the one class for several years. Some of the trusts I referred to earlier take a long time to develop - the best part of a year, if not longer. Once they are developed the quality of the whole class dynamics and the student learning can rise to levels which are extremely difficult to attain without them.

REFERENCES

AMIDON, E., and FLANDERS, N. (1963). The role of the teacher in the classroom. Minneapolis: Paul S. Amidon and Associates, Inc.

BAIRD, J.R., and MITCHELL, I.J. (Eds) (1986). Improving the quality of teaching and learning: An Australian case study - the PEEL project. Melbourne: Monash University Printery.

BARNES, D. (1976). From communication to curriculum. Penguin.

THEOBALD, J.H. (1978). Attitudes and achievement in biology: An investigation of the effects of student attributes and teaching styles on attitudes and achievements in secondary school biology. Unpublished Ph.D. Thesis.

Research in Science Education 1989, 19, 210 - 219

GOLD MINING IN PAPUA NEW GUINEA: A CURRICULAR OMISSION?

W.P. Palmer

INTRODUCTION

What criteria are used to include or exclude particular topics within a country's science curricula? It will be argued here that gold/gold mining is a suitable and relevant topic for inclusion in P.N.G.'s science curricula and suggestions towards achieving that end will be offered. The teaching of the mining of copper ore and the metal's extraction are already a well established feature of the science curriculum being taught at Grade 10 and Grade 11 (Ponnamperuma and Palmer, 1987). Amongst the reasons for the inclusion of copper were that it was considered to be an appropriate introduction to chemical technology and that it had major economic importance. Other advantages are that there are a wide variety of experiments that can be carried out using copper and its compounds in school laboratories and at least some of its chemistry is relatively straightforward. Owens (1980,p 135; 1987, p 161) however argues for a larger number of practical applications of chemistry being included in school curricula. Waddington (1987) points to some of the dilemmas facing science teachers introducing new ideas linking science technology and society and considers that relevance and the ability to inspire future scientists and technologists are important factors in determining science curricula worldwide. Fensham (1987) expands on the idea of relevance and shows that for Australian chemistry curricula little knowledge of industrial chemistry is now required of students, whereas forty years ago industrial chemistry made up a considerable proportion of the curriculum. In this context a unit on gold and gold mining might well be a sensible choice at Grade 10 or 11 level in Papua New Guinea to extend the pupils' knowledge and understanding of the interactions between science, technology and society. In general terms students studying a unit on gold would be able to explore these interactions more thoroughly than studying the units on copper, but practical work based on the extraction of gold or the chemistry of gold is limited due to its high cost, the low concentrations of gold present in its ores and the poisonous nature of the chemicals used for extraction. However the possibilities of school visits to gold mines are greater because there are increasing numbers of gold mines operating. The links between gold mining, society and technology are particularly strong. Gold mining has strong historical links to the exploration of the country (Gash and Whitaker, 1975 pp 245-274). Politics, law economics, and current affairs link the future of current and prospective mines with the divergence of view about the nature of land ownership in customary (Melanesian) tradition and imposed European law (Times, 23 June 1988, p6) (Times, 12 January 1989, p 16) (Note 1). This for example, is one of the root causes of the disagreements with regard to the copper/gold mine at Panguna. The difficulties of finding sufficient jobs for educated young people is high on the political agenda in Papua New Guinea and the opening of new mines will certainly help to provide employment. On the other hand the opening of mines may well cause environmental damage which prevents farmers and fishermen continuing to provide for themselves in traditional ways. The sciences of physics, chemistry, geology, geography, engineering, ecology and technology are all interwoven in the study of this topic and this paper will study these linkages. The method chosen will be to give some basic information about gold, explaining the theme from the historically earlier and technologically simpler methods to the more complex modern processes and choosing particular mines as examples of these processes. Background from books and journals will be supplemented by articles from newspapers, particularly Papua New Guinea newspapers. This is because secondary teachers in Papua New Guinea have very limited resources available to them. This paper aims to act as a model so that teachers can then build up their own collections of cuttings from newspapers. Because the rate of expansion of mining is so rapid, it is a frequent news item for local newspapers and this would allow a file of information to be built up comparatively quickly.

OCCURRENCE

Gold is widely distributed in nature, combined or in the free state, associated with other elements such as sulphur, silver, copper, selenium or telurium. (Avraamides et al., 1989). South Africa has the world's largest reserves of gold and currently supplies more than half the world's gold, outside the Eastern bloc nations (South, January 1988, pp 11-12). Indeed political disapproval of South Africa, particularly of its racial policies, may well militate against the inclusion of gold in science curricula worldwide. South Africa's supremacy in the production of gold is being challenged by the emerging nations of Africa, South America and the Pacific which are gradually increasing their production, (South, March 1989, pp 8-11). In the countries of the South Pacific on the so called "rim of fire", the plates forming the earth's crust grind together, and complex geological processes bring increased concentrations of many metal ores including gold near to the surface (Jackson, pp 5-10). Figure 1 indicates known mines and projects on the rim of fire.

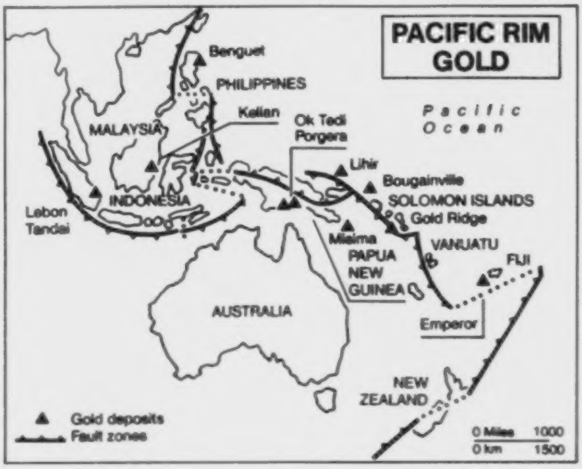
PACIFIC RIM GOLD
Benguet
PHILIPPINES
Kelian
Ok Tedi
Porgera
Pacific Ocean
MALAYSIA
Lihir
Bougainville
SOLOMON ISLANDS
Gold Ridge
INDONESIA
Lebon Tandai
Misima
VANUATU
FIJI
PAPUA NEW GUINEA
AUSTRALIA
Emperor
NEW ZEALAND
▲ Gold deposits
Fault zones
0 Miles 1000
0 km 1500

Figure 1 Times, 9 April 1987, p 23.

Historically this area has produced gold since the fourth century AD when Chinese miners were active in Indonesia: gold was found in Fiji in 1868 (Bonato et al, 1987) and was observed in local pottery in Papua as early as 1852 - (Healy, 1972). There are currently thirty known mineral sites needing further investigation and at least twelve of these are being mined or under active consideration. (P.C, 13 September 1984, p 13).

Which mines actually develop and which remain as golden dreams depends on many factors, but the factors will be a combination of the economics and the politics of the mine being considered. For example on Bougainville Island the extremely profitable Panguna mine has now shut down due to political disagreement about the distribution of the wealth which it produces. Others may never even start due to local disagreements which usually relate to the compensation to be given for loss of land. The likelihood of a mine being opened quickly increases rapidly if it has a rich vein of gold which can be exploited easily so that capital can be generated to pay for a part of the mine's initial costs. Other factors which affect development are the quantities, type and concentration of the ore, the country's perceived stability and financial standing, labour costs, the terrain, the weather, the risk of earthquakes, proximity to a port etc. These are internal factors but the overall determining factor is the price of gold internationally, both current and predicted. The price of gold has varied widely and is itself determined by supply and demand. Thus it is only mines which are sure to be profitable, even if there was to be a major change in the gold price, that will be developed. Gold is curious amongst the metals in that it has only a limited number of uses. Most gold is stored as an accepted measure of an individual's or a country's wealth. Gold only has its current high value because people believe it to be valuable. Without that fundamental and widespread belief in gold's value none of the gold mines being considered would be started. A further incongruity in considering gold as a topic for study is that a logical sequence of curriculum development has at its root humanity's illogical desire for gold.

THE MINING OF ALLUVIAL GOLD: BULOLO AND WAU

Gold contained in veins in gold-bearing rock, usually quartz, is called reef gold. When this rock is weathered and eroded the sand and gravel from it contain alluvial gold: these are called placer deposits, which are usually the first gold to be discovered. Prospectors separate the gold from the surrounding material by "panning". The mixture is whirled round and round with water repeatedly discarding the lighter mud, sand and gravel, usually leaving the denser gold with some grains of black sand in the pan. Hard labour is needed to obtain just a few grams of gold as large amounts of gravel must be panned. An improvement on panning is to use a sluice box which is usually a large wooden construction with transverse strips of wood, riffles, set into its bottom. The box is inclined between 5° and 30° to the horizontal and the gold collects above the riffles (Stewart, 1986). There are currently about 4,000 small scale P.N.G. miners mainly earning their living from alluvial gold, using either panning or sluicing methods. They obtain their gold as follows. The product of panning or sluicing is mixed with liquid mercury, which dissolves the gold forming an amalgam leaving sand and gravel undissolved. The amalgam is then heated in a furnace, "retorted", leaving a residue of gold or a gold/silver alloy. Mercury vapour is extremely dangerous to human health and mercury when dissolved is harmful to the environment. Blowers and Mallard (Times, 22 August 1986, p 21) carried out a survey to check the effects of mercury on human health and on the environment in the Wau/Bulolo area. They detected very little harm caused by mercury in the environment or in individuals. Large scale mining of the flats of the Bulolo river valley was planned in 1925. (Times, 19 January, 1989, p16). Huge floating dredges were needed to implement these plans and the parts for these dredges were flown in and assembled on site. There were eventually eight working dredges weighing up to 2600 tons each, and these operated from 1938 to 1942, when the mines were closed (Nelson, 1982). After the war mining was restarted, but costs had increased and the price of gold was fixed. So dredging was brought to an end in 1965 (Healy, 1972), but the rusting dredges can still be seen today. Nuigini Goldfields continues to operate successfully in the area (Times, 8 August 1986, p23) and Hidden Valley, near Wau, awaits government permission before production can start (Times, 27 April 89). A further alluvial project in Gulf province near Malalaua at Lakekamu may be developed by City Resources using big dredges like those formerly used at Bulolo (Times 8 September, 1988, p 24). The Lakekamu ore is low grade, but has a large volume and a mine sited there is said to be "viable, affordable and about to happen". (Times, 9 April 1989, p25). Thus dredges similar to those that now lie abandoned and rusting may once more be seen in action, perhaps by 1991. Nonetheless it must be hoped that in the new situation more is done to return the land to its former fertility than has been the case at "Dead Valley" Bulolo, where the top soil has been destroyed and is now useless for agriculture (Mueller, 1988) (Times, 25 May 1989, p17).

COPPER AND GOLD: BOUGAINVILLE AND OK TEDI

Copper is the main product for both the Bougainville and Ok Tedi mines, but both are also major producers of gold and silver too. The Bougainville deposit was discovered in 1964 (Haddon-Smith) and the mine began production in 1972. Since that time the mine has been of major economic benefit to the P.N.G. economy contributing about one third of the country's G.N.P. Although there is sufficient ore to continue production until the turn of the century the mine is currently closed due to a dispute with the landowners which has become, for all practical purposes, a civil insurrection against the P.N.G. government. The original agreement was imposed against considerable local opposition and it may be that more generous terms provided for recent mining agreements have caused landowners to feel dissatisfied with own compensation. Certainly good economic management at the mine has made it very profitable in spite of decreasing grades of ore, so over the next few months considerable efforts will be made to resolve the conflict. Apart from financial compensation there is the question of environmental damage. The Jaba river has become badly polluted by sediment and heavy metals. The mine and some pollution can be seen in photographs taken by the author which are now used in P.N.G. high schools. The Ok Tedi mine is in some ways similar but is situated in a more geographically remote area so that any environmental damage is less obvious. A report (Mowbray 1986 p73) recommended "Ways must be found to reduce levels of suspended solids immediately and to ensure high levels of copper and free cyanide in the tailings are also reduced". It would appear that little action has been taken on the report's recommendations as recently the Ok Tedi river has been described as a sewer (Times, 1 June 89, p3). The discharge from mines can pollute rivers in a number of ways. Firstly the crushed rock from which the ore has been extracted can enter the river as a fine mud which the river carries away. Secondly heavy metals normally trapped within the rocks can be released and accumulate in particular aquatic species. Thirdly dangerous chemicals such as sodium cyanide used by the mining company when treating ores may also escape from the mine. Each of these problems can affect local people dependent on river water in different ways. The Yonggom people have been adversely affected but received no compensation for the destruction of their way of life. The initial stage of the Ok Tedi project was to remove the surface layer from "the gold topped mountain" (T.E.G, June 1983, p23). The gold was extracted by the usual carbon pulp-cyanide process and the cash-flow generated used to pay for high initial costs. The sodium cyanide needed for this process was brought most of the way by barge. One barge lost its cargo of cyanide drums in a storm in the Fly estuary. The Post Courier index can be used to tell this story quite dramatically as follows:-

CYANIDE LOST NEAR FLY MOUTH (19 June) - WEATHER HAMPERS SEARCH (21 June) - PLEASE DO NOT TOUCH CYANIDE DRUMS (25 June) - SECOND CYANIDE SPILL SHUTS GOLD PLANT (4 July) - KEEP SEARCHING ORDER ON CYANIDE (13 July) - RISKY TO SALVAGE DRUMS (30 July) - NOW 138 DRUMS FOUND (18 October) - CYANIDE INQUIRY TO BE SET (5 November) - CYANIDE INQUIRY INDECISION (10 December).

This outline story could well be used as an opportunity for imaginative essay writing. The original design for the Ok Tedi mine included plans for a tailings dam at Ok Ma (T.E.G. June 1983, p 26), which if built would have obviated the problems described above. It has never been completed due to a mudslide (P.I.M., March 1984, p29) at an early stage of construction (P.C, May 7, 1984, p3). As an interim measure tailings were treated with hydrogen peroxide to destroy free cyanides and heavy metal cyanide complexes and these soluble products were then precipitated in alkaline solutions (Degussa 2, 1988). Later reports (Times, 1 March 1986, p3) indicate that the tailings dam will never be built. The P.N.G. government and a number of experts, for example Brooks (P.C. 25 April, 1986, p5) consider that the damage to the environment is more than balanced by the good the income from the mines does in helping the development of P.N.G. Others find the environmental cost too high. This is an important area to discuss with students.

THE PORGERA PROJECT AND MODERN GOLD EXTRACTION

Porgera has sixty million tonnes of moderate grade ore containing 6.5 g of ore per tonne. (Times, 18 May 1989, p21) and will be mined using a combination of open pit and underground mining (Times, 9 February 1989, p18). The ore will be ground into a fine powder, after which any free gold will be removed using gravity recovery. The mine's power will come from electricity produced from natural gas from the Hides field. Flotation will remove sulphide ores which will be oxidised by heating in autoclaves. A standard cyanide leaching process will be carried out using carbon in pulp which eventually yields particulate gold and silver. These products are melted and cast into bars of gold-silver alloy ready for futher purification. The major cause of disagreement regarding the plans for the Porgera mine is the provision of a tailings dam. The company believes a tailings dam will pose a greater risk to the environment than the continual dumping of waste into the Strickland river sytem (Times 2 March 1988, p1). Although there has been considerable political infighting about this (Times 19 June 1989, p1) it now appears that mining will go ahead without a tailings dam, but it will have a much less expensive tailings neutralisation plant (Times, 9 February 1989, p3). Other gold mines are in prospect at Misima, (Times, 5 September 1986, p18), at Lihir Island (Age Extra, 12 May 1988, p1), at "Wild Dog" reef in East New Britain (T.R.S. May 17, 1986, ,p3), at Mount Nakru in West New Britain (Kalowin, 1988, p4 and p25), at Wapolu on Ferguson Island (N.G.N. 26 Jan 1987, p3), and at a variety of other sites which space does not permit the author to describe.

CONCLUSION

The topic of gold/gold mining contains an admixture of ideas from a variety of disciplines which with further curriculum development can lead to a fully integrated course for year 10 or 11 in P.N.G. high schools. The politics of mining at the present time in P.N.G. might well encourage many companies to help in that curriculum development by providing booklets and other curriculum materials to schools, such as those the mining industry in Australia has already provided for Australian schools (Note 2).

NOTES:

1. In general newspaper and popular magazine articles will be referenced briefly within the text, whereas books and academic journals will be referenced fully. The following abbreviations will be used: The Age (Age), New Guinea Nuis (N.G.N), Pacific Island Monthly (P.I.M.), Post Courier (P.C.), South (South), The Times of Papua New Guinea (Times), The Times of Papua New Guinea Export Guide (T.E.G.), The Times of Papua New Guinea Regional Survey (T.R.S.).
2. The author would be willing to send a fuller version of this paper to anyone expressing interest in this topic. Address: C/- Faculty of Education Northern Territory University PO Box 40146 CASUARINA NT 0811 AUSTRALIA.

REFERENCES

AVRAAMIDES, J., DUNN, J., GRAHAM, J., JUST, J., & NGUYEN, G. (1989): The production of gold In I. Irvine (ed), In *Chemistry in an Australian Context Sourcebook*. Royal Australian Chemical Institute, Parkville, Victoria, Australia.

BONATO, J.A. (1987): Gold extraction In J.A. Bonato, J.B. Headbridge, and R.J. Morrison (eds) *Chemistry Serves the South Pacific*, University of the South Pacific, Fiji, pp 100-107.

DEGUSSA 2 (1988): Hydrogen peroxide: detoxifying mine effluents containing cyanide. (Company booklet No.2), South Melbourne Victoria.

FENSHAM, P.J. (1987): Changing to a science society and technology approach In *Science and Technology Education and Future Human Needs* J.L. Lewis & P.J. Kelly (eds) I.C.S.U./Pergamon Press, Oxford, UK, pp 67-80

GASH, N. & WHITTAKER, J. (1975): *A pictorial history of New Guinea*, The Jacaranda Press, Milton, Queensland, pp 258-274.

HADDON-SMITH, K. (undated): *Bougainville Copper*, Bougainville Copper Ltd., P.N.G.

HEALY, A.M. (1972): Goldfields In P. Ryan (ed) *Encyclopaedia of Papua and New Guinea*. Melbourne University Press, pp 99-501.

JACKSON, R. (undated): *The Pot of Gold*, University of Papua New Guinea, Port Moresby.

KALUWIN, C. (1988): Chemistry and mining in P.N.G. *Chemistry in Papua New Guinea*, 4 (2) November, pp 6-9.

MOWBRAY, D.L. (1986) Biological Input of Ok Tedi mine tailings, cyanide and heavy metal on the Ok Tedi Fly River Ecosystems in Papua New Guinea: *Report to the Bureau of Water Resources*, 10 September, U.P.N.G.

MUELLER, N. (1988): *Protecting the Environment: a call for support*, Wau Ecology Institute, Wau, P.N.G.

NELSON, H. (1982): *Taim bilong master*, A.B.C., Sydney, Australia. pp 141-148.

OWENS, C.M. (1980): Analysis of some chemistry curricula in Papua New Guinea: Unpublished M.Sc. thesis, University of East Anglia, UK.

OWENS, C.M. (1986) Chemistry and everyday life In P. Bladon (ed) *Chemistry in the Service of Papua New Guinea* Papua New Guinea Institute of Chemistry, Goroka, P.N.G., pp 153-166.

PONNAMPERUMA, A.C.W. & PALMER, W.P. (1987): Introducing the chemical industry into the science curriculum in Papua New Guinea in *Education, Industry and Technology*, I.C.S.U. Press/Pergamon Press, Oxford, UK, pp 133-138.

STEWART, D.F. (1986): Gold recovery in a sluice box: Papua New Guinea practice In P. Bladon (ed) Chemistry in the service of Papua New Guinea, 12-14 September, Papua New Guinea Institute of Chemistry", Goroka, P.N.G. pp 49-56.

WADDINGTON, D.J. (1987): Introduction, Education, Industry and Technology, I.C.S.U. Press/Pergamon Press, Oxford, UK.

Research in Science Education 1989, 19, 221 - 230

MEASURING STUDENTS' ATTITUDES AND PERCEPTIONS ABOUT TECHNOLOGY: A MULTIDIMENSIONAL CONCEPT

Leonie J Rennie and David F Treagust

The purpose of this paper is to describe an affective scale which has been designed to measure students' attitudes and perceptions about technology. The need to develop the scale came from efforts to evaluate two separate curriculum projects in primary and secondary schools in Western Australia. The first of these at the upper primary level was a project sponsored by the Technology and Industry Development Authority, which developed three technology modules: Recreational Technology and Toys, The Perth Zoo: A New Look, and Technology and Leisure. Subsequently, a grant from the Curriculum Development Centre has been used to implement a trial and evaluation of these modules (Kinnear, Treagust & Rennie, 1989). As part of this evaluation, an affective instrument suitable for use with children aged 10 to 12 years was required.

The secondary school technology project was initiated by the Ministry of Education in Western Australia, which invited schools to submit a proposal to become Technology High Schools. Six schools were funded to introduce technology into their curriculum, and each school is now working to do this according to their own plans. As their curriculum goals were formulated, the technology education coordinators from the two Technology Senior High Schools in metropolitan Perth requested assistance with an instrument to assess changes in students' attitudes and perceptions about technology throughout the school year.

MEASUREMENT OF STUDENTS' ATTITUDES AND PERCEPTIONS ABOUT TECHNOLOGY

The most extensive research into students' attitudes about technology has been carried out in the Netherlands as the Pupils' Attitudes Towards Technology (PATT) Project (Raat & de Vries,1986; Raat, de Klerk Wolters & de Vries,1987; Raat, Coenen-van den Bergh, de Klerk Wolters & de Vries, 1988). In this project two questionnaires, an attitude instrument and a concept instrument, have been developed on the basis of comprehensive trials in more than a dozen countries around the world, including Australia (Rennie & Parker, 1985). The attitude instrument developed by the PATT project questionnaire contains 60 Likert-type items with a five-point response format including an undecided category. There are six subscales measuring interest, gender, consequences, difficulty, curriculum and careers in technology. The 28-item concept instrument has a three point (agree - disagree - don't know) response format. Both instruments have been developed for students aged 13 to 15 years.

In addition to the questionnaires, several countries have used the PATT essay topic to explore, in a less direct way, the opinions and perceptions students have about technology. Rennie and Sillitto (1988) reported on the use of the essay topic in a Western Australian sample of 13-year-old students. A number of other projects in the Netherlands and elsewhere have made use of the instruments developed in the PATT studies.

In this paper, the development of the Attitudes and Perceptions About Technology scale is described. The development has been in two stages. In the first stage, a questionnaire was prepared for use in the upper primary levels, and in the second stage, a longer version of this instrument was adapted for use at the secondary level.

DEVELOPMENT OF THE ATTITUDES AND PERCEPTIONS ABOUT TECHNOLOGY SCALE

Stage 1: Primary School Version

The questionnaire to be used in the primary schools was required to measure the students' attitudes and perceptions about technology, and particularly their understanding of technology as a problem-solving, design process, which was the integrating feature of the modules developed in the Primary Technology Project. Another aspect of the project was its focus on the inclusion of girls, and so additional items of the questionnaire were needed to reflect this aspect of the project. The development of the questionnaire began with a pool of 42 items. A number of items referring to interest and careers in technology, its difficulty, and gender in technology were selected from the PATT attitude scale (Raat et al, 1987), and reworded slightly to match more closely the target age group of 11- and 12-year-olds. Additional items were written to reflect the design process perspective used in the modules. The contents of the items were given face validity by members of the project team.

Because the children were younger than the PATT study group, and because the questionnaire included items about the nature of technology, as well as attitudes towards it, a three point, rather than a five point, response format was used. The three response choices are agree - don't know - disagree. Students were asked to use the 'don't know' response if they didn't know,

weren't sure or couldn't decide. A preliminary trial of the questionnaire with a small group of 11-year-old students indicated no confusion with, or ambiguity in, the wording of the items, nor the directions for response.
The 42-item preliminary questionnaire was piloted using seven classes from two government primary schools. One school was situated in an area of low socio-economic level and, as it was a small school, had only one class at each of the seven grade levels. The Years 5, 6 and 7 classes all completed the questionnaire. The second school was larger and situated in an area of middle socio-economic level. The two Year 7 classes, a Year 6 class and a split class of Year 5 and 6 students completed the questionnaire. The questionnaires were administered by the usual class teacher, who was asked to assist any child needing help, but not to discuss technology nor its meaning until after the questionnaires were collected. No teacher reported any difficulties in administering the questionnaire.

There were 83 boys and 73 girls in the pilot sample. The responses were scored 1 for disagree, 2 for don't know and 3 for agree. Analysis of the responses to the 42 items resulted in the deletion of eight items. Six items were deleted because they had means close to the extreme representing a positive attitude or perception about technology, and thus would be likely to show a 'ceiling effect' if the technology questionnaire was used in a pretest-posttest administration. Two further items were deleted because they had very low inter-item correlations. The final version of the scale contains 27 items measuring students' attitudes and perceptions about technology. In addition, there are seven items focussing on gender issues.

The primary school version of the Attitudes and Perceptions About Technology scale has been administered to eight classes in the seven schools where the three primary technology modules are being trialled. Students have completed the questionnaire prior to and after doing the topic as part of the evaluation of the modules. In this paper, however, no results of analysis comparing the pre and post test data are reported (see Kinnear et al, 1989).

Stage 2: Secondary School Version

The need for an instrument to measure students' attitudes and perceptions about technology arose when teachers at the two largest technology schools began to search for a way to evaluate the work they were doing in implementing technology into the curriculum in their schools. The smallest of the technology schools, a district high school, had already used the primary version of the questionnaire because it was trialling one of the technology modules in its primary grades. Partly for this reason, and partly because of the need for a fairly short questionnaire, the secondary school version of the Attitudes and Perceptions About Technology scale was based on the primary version of the instrument. Development of the secondary questionnaire began with the 27 items measuring attitudes and perceptions about technology. Six new items were added about the meaning of technology, which increased the length to 33 items. The three point response format of the Primary Technology Questionnaire was retained, and the same directions were used. Although it was not a focus of the secondary project, the seven gender items supplementing the primary version were also included in the instrument at the request of one of the teachers, but were not considered to be part of the scale.

ADMINISTRATION AND ANALYSIS OF THE ATTITUDES AND PERCEPTIONS ABOUT TECHNOLOGY SCALE

The scale was administered by classroom teachers to all of the Year 8 students in two Perth Metropolitan Senior High Schools. The sample of 506 students comprised 299 boys and 207 girls. The detailed analysis presented here is based on this sample of students. The first analyses focused on the response distributions of the 33 items. A feature of the results from the PATT studies was the high frequency of use of the 'don't know' response, particularly for females. This seemed to reflect both a lack of knowledge and an unwillingness to make a commitment to either agree or disagree with the statement (de Klerk Wolters,1987; Rennie,1988). In the present questionnaire, the 'don't know' response was used by 25% or more of the sample on 29 of the 33 items, and on 32 of the items, a greater proportion of girls than boys chose this response. Perhaps not surprisingly, for students of this age, the three items referring to a career in technology attracted the highest proportion of "don't know" responses.

The items were scored 1, 2 and 3 for the disagree, don't know and agree categories, respectively. Items with negative wording were reverse-scored. The decision about including the 'don't know' responses in scoring the items was not made lightly. Shrigley and Koballa (1984), in referring to the usual five-point Likert response format, recommend that "good" attitude items should cluster at each end of the response continuum. Further, they suggest that an item with an undecided response rate of 25% or higher should be considered "suspect". The situation is different here. Many of the items refer to perceptions about what technology is, rather than students' emotional reactions towards it, and previous research suggests that many students of this age have little knowledge about technology (Rennie & Parker 1985; Rennie & Sillitto, 1988). In fact, if the technology curriculum program is successful, a major outcome will be the clarification of students' attitudes and perceptions about technology, which would be reflected in a lower usage of the "don't know" category when the posttest is administered.

The dimensionality of the instrument was determined using both parametric and nonparametric techniques. The reason for this related to the use of a three- point response format, which made the assumption of interval measurement rather risky. The parametric analysis first considered inter-item correlations, means and standard deviations of the items. Items which had low inter-item correlations (<.2), means close to the extremes (<1.3 or >2.7) and small standard deviations (<0.6) were identified. Eight items were identified as having one of these undesirable criteria. The nonparametric examination of items was based on a dichotomous scoring of the items, using 1 for agreement with the positive direction of the item and 0 otherwise. The criteria set for satisfactory performance related to the mean (<.2 or >.8) and inter-item correlations (phi >.2). Three items failed this scrutiny on both examinations. These were items 7, 11 and 39 which had low inter-item correlations. These items were deleted from further analysis.

The remaining 30 items were subjected to a principal components analysis and a cluster analysis. The principal components analysis resulted in the extraction of 9 components with eigenvalues greater than unity accounting for 56.4% of the variance. However, a scree test indicated that seven components was an acceptable solution (the eighth and ninth components had eigenvalues less than 1.1), and so seven components were rotated using a varimax rotation. The resulting solution is shown in Table 1. Reference to the item wording indicated that Factor I was an interest factor. Factor III contained the three items relating to a career in technology, and thus the overlap of these three items with Factor I is clearly interpretable. The items loading on Factor II refer to technology as a design process, and those in Factor V refer to the diversity of technology. Item 13, which has its variance split between these two factors, reads "In technology there are opportunities to think things up for yourself". Factor IV contains three negatively worded items which suggest that you have to be clever to study technology, and so refer to difficulty. The items forming Factor VI refer to technology as a way of problem-solving and the two items of Factor VII relate to the importance of technology.

Table 1 Factor Loadings for Seven-Factor Solution of the Attitudes and Perceptions About Technology Scale (Varimax Rotation)

Item	I	II	III	IV	V	VI	VII
21	.84						
15	.75						
28	.72						
29	.71						
32	.66						
22	.65						
37	.55						
4		.67					
14		.55					
18		.52					
5		.51					
2		.49					
13		.47			.36		
34		.36					
12	.38		.72				
27	.44		.70				
23	.47		.64				
8				.75			
26				.73			
3				.71			
40					.62		
38					.61		
36					.53		
35					.51		
1					.39		
6						.81	
9						.63	
16						.61	
17							.77
20							.74

Note: Only factor loadings exceeding .30 are reported

The second investigation of the dimensionality of the data used an average linkage cluster analysis based on the matrix of phi correlation coefficients. It was found that a six cluster solution gave precisely the same grouping of items as the factor analysis, except that the interest and career items were clustered together. On this basis it was decided to investigate the formation of subscales from the 30 items. Seven scales were formed following the grouping of items from the factor analysis, and means, standard deviations and alpha reliability coefficients are reported in Table 2. The means are reported as mean item scores using the three point response scoring method. The items which form the seven scales are obtainable by request from the authors.

Table 2 Statistics for Subscales of the Attitudes and Perceptions About Technology Scale

Factor	Scale Name	Number of items	Mean *	SD	Alpha
I	Interest	7	2.21	.54	.84
II	Career	3	2.03	.56	.82
I and III	Interest/Career	10	2.15	.48	.87
II	Design	7	2.54	.35	.56
IV	Difficulty	3	2.43	.58	.63
V	Diversity	5	2.01	.46	.46
VI	Problem solving	3	2.44	.51	.53
VII	Importance	2	2.45	.56	.43

* Means are reported as the mean item score

The Interest scale comprised seven items, and typical items read "I would like to learn technology at school" and "I am interested in technology". The Career scale included three items such as "I would enjoy a job in technology". These two scales had a correlation of .57, and could be combined to form a single ten item scale. The statistics for this combined scale are included in Table 2. The seven items forming the Design scale referred to technology as a design process and included items referring to designing, making and testing models. Typical items are "In technology there are opportunities to think things up for yourself" and "Making things is part of technology". Two three-item scales referred to technology as a Problem-solving process ("Technology is finding the best solution to a problem") and the Difficulty of Technology ("You have to be clever to study technology"). Seven negatively worded items which perceived technology rather narrowly, in terms of its products, were grouped together into a scale which was named Diversity. It included items such as "Technology mainly concerns computers and similar equipment". The final two items referred to technology as important and needed by everyone, and were grouped under the heading Importance.

The mean item scores for the subscales are all above 2.00. In particular, students appear to have positive perceptions about technology as a design and problem solving process, and that people do not have to be clever to work in technology. The reliabilities of the subscales vary between .43 for the two-item Importance subscale and .87 for the ten-item Interest/Career scale. The low reliabilities of the Problem-solving and Importance subscale could be improved by adding additional items as the concepts are clear-cut. The Diversity subscale, is more complex. The items are varied and their common element (as they are negatively worded) is a narrow conception of the nature of technology. The addition of other items would need careful consideration.
The subscales are conceptually distinct, and the correlations between them, reported in Table 3, indicate that when the Interest and Career scales are combined, they are empirically distinct. The intercorrelations are generally low, and although some are statistically significant (a function of the large sample) they are not practically significant. This finding lends support to the divergent validity of the subscales.

Table 3 Correlations between the Subscales of the Attitudes and Perceptions about Technology Scale.

	Interest/ Career	Design	Difficulty	Diversity	Problem Solving
Interest/Career					
Design	.08*				
Difficulty	.12*	.06			
Diversity	.08*	.11*	.24**		
Problem-solving	.14*	.21**	-.05	.05	
Importance	.06	.07	-.04	.02	.10*

* p < .05 ** p < .01

This paper has described the development of an instrument, Attitudes and Perceptions About Technology, which was developed and trialled with upper primary and lower secondary students in Western Australian schools. The 30 items (which had 27 in common with the primary version of the instrument) had a seven factor structure. The subscales formed from these factors had moderate to high reliabilities and their low intercorrelations demonstrated the multidimensionality of the technology concept. The instrument is currently in use in Western Australian schools to evaluate students' attitudes and perceptions about technology as a result of specifically designed programs for technology education at both the primary and secondary levels.

REFERENCES

KINNEAR, A., TREAGUST, D.F., & RENNIE, L.J. (1989). Trialling and Evaluation of Technology Curriculum Materials for Upper Primary Grades. Report prepared for the Curriculum Development Centre, Canberra.

de KLERK WOLTERS, F. (1987). Vier havo-vwo en een mbo over techniek. MENT - Project, Eindhoven University of Technology, Eindhoven, the Netherlands.

RAAT, J.H., COENEN-van den BERGH, R., de KLERK WOLTERS, F, & de VRIES, M. (1988). Report PATT-3 Conference Vol 1. Framework for Technology Education. Eindhoven University of Technology, Eindhoven, the Netherlands.

RAAT, J.H., de KLERK WOLTERS, F, & de VRIES, M. (1987). Report PATT Conference Vol 1. Proceedings. Eindhoven University of Technology. Eindhoven, the Netherlands.

RAAT, J.H., & de VRIES, M. (1986). What do girls and boys think of technology? Pupils' attitude toward technology. Eindhoven University of Technology, Eindhoven, the Netherlands.

RENNIE, L.J. (1988). How can we make technology interesting for girls? Invited address to PATT-3 Conference: Basic Principles of School Technology. Eindhoven University of Technology, Eindhoven, the Netherlands.

RENNIE, L.J., & PARKER, L.H. (1985). Technology Awareness: An International Survey. Proceedings of the Eleventh Annual Science Education Conference (pp. 59- 64), Western Australian Institute of Technology, Perth, Western Australia.

RENNIE, L. J., & SILLITTO, F.J. (1988). The meaning of technology: Perceptions from the essays of Year 8 students. The Australian Science Teachers Journal, 34(4), 68-76.

SHRIGLEY, R.L., & KOBALLA, T. R. Jr. (1984). Attitude measurement: Judging the emotional intensity of Likert-type science attitude statements. Journal of Research in Science Teaching, 21, 111-118.

Research in Science Education 1989, 19, 231 - 240

THAI CONCEPTIONS OF ILLNESS

Pranee Rice

INTRODUCTION

Australia is a multicultural society. Its population consists of a number of different ethnic groups as well as white dominant population. Table 1 shows that during the last few years there has been a signficant increase in the number of migrants from different Asian countries settling in Australia.

As can be seen, these Asians include not only refugees from war torn Vietnam, Kampuchea, Laos and Lebanon but those from East and Southeast Asia such as Filipinos, Malaysians, Chinese and Thais and Central and Western Asia such as India and Turkey. Migrant and refugee children are normally sent to Australian schools. They are, however, brought up within their own cultural systems. They often bring to school a view of knowledge which is considerably different from school knowledge. This is particularly so in science.

I argue that out of school knowledge has two forms: commonsense knowledge and cultural knowledge. By commonsense knowledge I mean the views of knowledge people develop from everyday interactions. This knowledge is often different from school science knowledge. It does, however, provide a very sensible and practical explanation to people who hold it (Watts, 1983). By cultural knowledge I mean the views of knowledge shared by the people in a group and learnt by their children. It is based on the experience of older generations and passed on to younger generations (Mandelbaum, 1968; Norman, 1981). Hewson and Hamlyn (1983), for example, studied the effect of cultural knowledge and physical environment on conceptions of heat of a Sotho group who live on the interior plateau of Southern Africa. The study showed that Sotho people used a variety of alternative conceptions including their cultural knowledge to explain heat phenomena. For example, they hold the notion that persons killed by lightning are said to be hot and should be buried in considerably cool places.

Table 1: Asian settlers in Australia, 1980-1988

Countries	1980	1981	1982	1983	1984	1985	1986	1987	1988
Kampuchea	1348	1741	2263	4440	880	1020	880	1560	2070
Laos	1404	655	405	370	500	104	238	*	*
Vietnam	12460	12285	8383	9370	9900	7260	7310	6270	8300
China	1456	1368	1073	1300	2600	3210	2680	3090	5290
Korea	223	409	741	560	570	*	*	1790	2500
Malaysia	1772	2157	2122	1870	1870	2360	2840	5080	11230
Philippines	2588	2969	3094	2660	2950	3750	4850	8960	15470
Singapore	555	636	710	590	670	*	*	1910	3010
Thailand	217	212	301	230	330	670	810	960	1430
India	883	1215	1622	1710	1730	2030	2140	2870	4870
Sri Lanka	294	440	543	740	2570	1600	2080	2970	4960
Lebanon	789	818	829	740	2440	2190	2840	3880	5120
Turkey	986	985	550	560	740	880	1090	1260	2030
Other	1522	3009	1871	1520	7000	6550	9020	11060	14420
Total	26497	28899	24507	26660	34750	31624	36778	51660	80700

Source: Australian Bureau of Statistics, Overseas Arrivals and Departure, Annual Report, 1980-1988.

*detail not provided

Differences in cultural knowledge and school science knowledge are quite pronounced. Maddock (1981) argues that children from Papua New Guinea, India and Thailand hold their own world views which are very different from school scientific views. From my doctoral research (1988) which was conducted in Thailand, I found that Thai schoolchildren used a large number of Thai cultural knowledge to explain concepts of health and sickness. For example, most children believe that people get sick because of their own kam resulted from misdeeds in their past lives. People can also get sick if they make supernatural beings angry and if they eat food which is salaeng (wrong) to their body.

These differences are important in the classroom. Teachers unaware of the gaps between cultural and school knowledge can unintentionally confuse themselves and their students, thus causing learning difficulties. On the other hand, knowledgeable teachers can draw on these differences to maximize effective learning. This article stems from my attempt to develop my doctoral research proposal. It discusses conceptions of illness held by one group of Asian migrants - the Thais.

Procedures

I interviewed three middle-aged Thai women who are resident in Melbourne. Two of them have been living in Melbourne for more than ten years while the other one came to Melbourne 7 years ago. They all have children and the children are educated in Australian schools. One has only secondary education. The others are university graduates.

The interviews were conducted using the "Interview-about-instances" technique (Osborne and Gilbert, 1979). Twenty pictures showing people who suffered from several illnesses were provided to investigate the interviewee's ideas of the concept of illness. They were asked to look at the pictures one by one and to respond briefly to each picture and then, after seeing all pictures, to discuss and give their own explanations. The interviews took about 30 - 40 minutes. They were recorded on tape and subsequently transcribed. All interviews were conducted in Thai. I used five main questions in the interview to stimulate the discussion.
These were:

1. Do you think people in the pictures are sick?
2. Why do you think they are sick/not sick?

3. What causes the sickness?
4. In your own ideas when people are sick what causes their sickness?
5. In Thai conceptions, why do you think people get sick?

Where I was unclear of the participants meaning I asked them to elaborate their explanations. Where appropriate I prompted with questions like: Could you exaplain it to me?. Would you like to tell me more about it?. What else that you think may cause sickness? and so on.

To analyse the data obtained, I used the "Conceptual Profile Inventory" technique (Erickson, 1979: Hewson and Hamlyn, 1985). The transcripts are carefully examined for the conceptions expressed by the participants in the interviews. The expressed conceptions, then, are extracted, categorized into groups, and a short description showing the conceptions used by the participants as a whole is produced. Word-by-word examples from the transcripts are presented to show the participants' expressions of each conception.

RESULTS

The results show that these Thai adults hold several conceptions about how people get sick. Their conceptions can be categorized into three groups. These include school science knowledge, commonsense knowledge and Thai cultural knowledge. It has been noted elsewhere (Textor, 1973; Kunstadter, 1978; Rice, 1988; Rice and Gunstone, 1986) that Thai people have their own cultural knowledge about causes of sickness which has been part of their culture for centuries. For example, kam (sin or retribution) is believed to be the root cause of any misfortune and suffering including sickness. It is the consequence of demerit accumulated by misbehaviour in the past. It can be transmitted to others in the family and transmitted from the past to the next reincarnation. It is believed to be effective sooner or later in the present or future. Thus, tam-di-dy-di (do-good-get-good) results in such things as good health, prosperity, birth in heaven and good fortune. On the contrary, tam-chua-dy-chua (do-bad-get-bad) has consequences such as misfortune, suffering, sickness in the present life, reincarnation in hell or in an animal form.

Ahaan salaeng is believed to cause illness. Most Thai people hold a strong belief that if one eats food which is salaeng (wrong) to the body one can get sick (Muecke, 1979). Furthermore, if one is sick and eats salaeng food one will get sicker. In 1987 Matichonraiwan, one of the popular newspapers in Thailand published that the majority of Thai women still believe that salaeng food can make them sick. Women are particularly prone to ahaan salaeng during pregnancy, post-natal and lactation. For example, pregnant women avoid eating such food as eggs and fish since they believe that they cause the unborn baby to be big and therefore it is dangerous for both mother and the baby. After giving birth women eat only rice with salt or rice with dried fish. Other kinds of food such as beef and scaleless fish are believed to salaeng to the womb and the body. That is the womb will not heal properly and the body will be weak.

Thai people believe that nature influences humans' well being. Man cannot interfere with nature. All human beings are subject to the circle of birth, old age, sickness and death. Sickness is also explained as due to the imbalance of the bodily elements. These are: din (earth), naam (water,) lom (wind) and fai (fire). If these four elements are in harmony, health maintains. Illness occurs whenever these elements are distorted. For instance, if one has too much wind in one's body, one will have a headache and stomachache. He/she may vomit and faint.

The categories of conceptions

In this section, the categories of explanations from the interview data are presented. Included are verbatim examples given by the subjects and their reference names.

Category		Exemplars
1.	School knowledge	
1.1	Germ: Sickness is caused by germ.	"...dropsy is caused by drinking water on the mountain that has little bugs in it." (JW) "a person who has flu because he is weak so he catches germ from other person easily."(NS) "... so I think it is caused by a germ."(PH)
1.2	physiological malfunction: Because of the physical malfunction, sickness exists.	"It may be because of the glands in the body. They work improperly" (JW) I think it is improper function of the hormones."(NS)

1.3 Poor nutrition and exercise: Too much or little food and exercise can cause sickness.	"I think it is because of the food... if we do not have enough food we will get sick easily."(JW) "This (malnutrition) is caused by lack of vitamin and food." (NS) "It is because of having too much food."(PH) "It is because of not enough food, exercise..."(NS)
1.4 Being run down: People who are tired and weak get sick easily.	"...sometimes it is because of not having enough rest." (NS) "... It is because the body is weak."(PH) "... women are always weaker than men when they have period. During this time they will get sick easier because the body does not have resistance to disease." (JW) "It is because of not having enough sleep.(NS)
1.5 Kam-ma-pan: Illness can be caused by heredity.	"It (epilepsy) may develop from the ancestors."(JW)

2. Commonsense knowledge

2.1 Parents: Parents cause illness during pregnancy.	"The mother takes pills without realising that it might hurt the baby". (NS) "They (the mothers) smoke and drink too much and ignore the doctor's warning." (NW) "... because the mother who is a drug addict consumes too many drugs." (PH)

	"Hare lip is caused by the father. He might go out and sleep with the prostitute and then take the disease back to his wife. When she is pregnant the disease affects the baby."(PH) "... may be the mother is too old to have a baby (then causes a hunchback)."(JH)
2.2 Emotional disturbance: If emotion is disturbed, sickness occurs.	"I think if the body is weakened because of ... emotion, the sickness will attack immediately." (PH)
2.3 Carelessness: Sickness is caused by carelessness and negligence.	"I think it is because of carelessness."(JW) "People who are sick as a result of accident have been careless and negligent."(PH)
3. Cultural knowledge	
3.1 Kam: Sickness is caused by evil deeds in the past.	"Wemkam, it is the kam of the child (who gets sick)." (JW) "... we do not know the real cause of illness so we blame wenkam." (NS) "...anyhow, hare lips in the village is believed to be a result of doing bad things to others. Therefore, it is your turn to get bad things. It is retribution." (PH) "I am not sure if the parents had done something wrong (to cause epilepsy) before she was born. I think it relates. When it came out like this they just blame wenkam." (PH)
3.2 Ahaan salaeng; Sickness results from eating wrong food to the body.	"She (mother) was not allowed to eat chicken or duck after giving birth... because it was bad for her body and would make her sick." (PH)

	"I cannot drink fresh coconut milk because it salaeng for me. It affects my period... anytime I drink it, my period disappears."(JW). "Men who have venereal disease do not eat breadfruit... because it is salaeng food and will make them sick." (NS).
3.3 Ghost possession: Sickness is caused by being possessed by a ghost.	"I have seen a person with a seizure who was sprinkled with montra water and casted katha-akom (incantation). It might be the case (of cause of sickness.) (PH)
3.4 Bodily elements: Imbalance of bodily elements results in illness.	"I have heard about it and I think it is true. The monks always say about this and I believe that is the truth." (PH) "When they have "wind illness", they will say that the Wind element has gone. My mother does believe and she can tell the specific element in a person too." (JW).
3.5 Nature: Nature determines human beings' well being.	"It is because of nature. Some children are born like this (born sick)." (PH)>

CONCLUSION

The findings show that these Thai people have their own ideas about the natural world. They use several explanations to explain how people get sick. School science knowledge is used. They apply their commonsense knowledge they perceived from everyday life to their explanations. More importantly, they make use of their cultural knowledge. They hold their cultural knowledge very strongly despite having lived in a western society and having had a high education. Their knowledge, cultural knowledge in particular, certainly impinges upon the understanding of their children. It has been suggested that the way in which children make sense of their world is influenced by their cultural knowledge (Norman, 1981). Children develop their cultural knowledge by learning and absorbing from their family and culture in which they grow up (Maddock, 1983). Prout (1985) argues that when dealing with illness there is a set of "cultural practices - practices which embody the knowledge and simultaneously reproduce and maintain it as taken-for-granted. Not only what my mother said but what she and I do and therefore learn"(p.404).

In the science classroom in a multicultural society like Australia, children from a diversely cultural background frequently bring with them a view of knowledge. This knowledge is often very different from that held by science teachers or that of school knowledge. As a result, learning problems arise. A basic understanding of the knowledge held by people from different cultures is therefore essential for science teachers.

One last point I wish to make is that these findings are consistent with my doctoral research which was conducted with Thai schoolchildren in Thailand. There are a number of conceptual similarities on Thai cultural knowledge between Thai schoolchildren and these Melbourne adults. It suggests that Thai cultural knowledge appears to retain its strength among the Thais.

REFERENCES

AUSTRALIAN BUREAU OF STATISTICS (1980-1988) Overseas arrivals and departures: Annual report. Commonwealth Government Printer.

ERICKSON, G. (1979) Children's conceptions of heat and temperature. Science Education, 63, 221-230.

HEWSON, M. G. & HAMLYN, D. (1984) The influence of intellectual environment on conception of heat. European Journal of Science Education, 6, 245-262.

KARGBO, D. B., HOBBS, E. D. & ERICKSON, G. L. (1980) Children's beliefs about inherited characteristics. Journal of Biological Education, 14, 137-146.

KUNSTADTER, P. (1978) Do cultural differences make any different? In KLEINMAN, A. et al. (ed.) Culture and healing in Asian societies. Cambridge, Schenkman Publishing Co.

M REPORT (1986) Mother of the nation: What to eat?... Why? Matichonraiwan, 3101, September 1.

MADDOCK, M. N. (1981) Science education: An anthropological viewpoint. Studies in Science Education, 8, 1-26.

MADDOCK, M. N. (1983) Science teaching, world view and attitude development. Paper presented at the International Symposium on the Cultural Implications of Science Education, Zaria, Nigeria, November.

MANDELBAUM, D. G. (1968) Cultural anthropology. In SILLS, D. L. (ed.) International Encyclopedia of the Social Sciences. The United States, The Macmillan Company and The Free Press.

MUECKE, M. (1979) An explanation of the wind illness. Culture, Medicine and Psychiatry, 3, 267-300.

NORMAN, D. A. (1981) Twelve issues for cognitive science. In NORMAN, D.A. (ed.) Perspectives on cognitive science. New Jersey, Alex Publishing Co.

OSBORNE, R. J., & GILBERT, J. K. (1979) Investigating student understanding of basic concepts using an interview-about-instances technique. Research in Science Education, 9, 85-95.

PROUT, A. (1985) Science, health and everyday knowledge: A case study about the common cold. European Journal of Science Education, 7, 399-406.

RICE, P. L. (1988) Health and sickness: The influence of cultural knowledge and commonsense interpretations among Thai schoolchildren. Ph. D. thesis, Monash University.

RICE, P. & GUNSTONE, R. F. (1986) Health and sickness causation and the influence of Thai culture among Thai schoolchildren. Research in Science Education, 16, 63-72.

TEXTOR, R. B. (1973) Postor of the gods: An ethnography of the supernatural in a Thai village. New Haven, Human Relations Area Files, Inc.

WATTS, D. M. (1983) Some alternative views of energy. Physics Education, 18, 213-217.

Research in Science Education 1989, 19, 241 - 248

DESPERATELY SEEKING SCIENCE (AND TECHNOLOGY?)

R.A. Schibeci

ABSTRACT

This paper describes sources of science and technology education in a metropolitan area. The sources are classified into three groups: government or semigovernment, private organisations and tertiary institutions. Issues relating to these sources include the adequacy of the provision of information for interested adults, the 'user pays' principle in relation to some of these sources and the notion of 'public understanding of science'.

INTRODUCTION

This paper describes the second phase of a project entitled Adult scientific and technological literacy. The project has two purposes. The first, and theoretical, aim is to develop a model of scientific and technological literacy which is grounded in practice. The second and practical aim, is to help to put interested adults in touch with sources of science and technology information.

SURVEY OF AN ADULT SAMPLE, 1988

The first phase of the project, a telephone survey of a sample of 256 adults in the Perth metropolitan region was conducted in 1988. The overall intention of the survey was to gather information on a variety of topics. The categories of information sought from the respondents included the following: (1) perceptions of the level of education of self and others in the areas of science and technology; (2) attitudes towards science and technology in general, as well as attitudes towards scientists; (3) extent of level of knowledge in particular areas of science and technology; (4) perceived need for specific information in areas such as medical problems and gardening; (5) with regard to (4), whether respondents have access to such information; (6) use of media by respondents; and; (7) some demographic information.

The findings of this survey were compiled into a report, Adult scientific and technological literacy: Report of a survey in Perth, Western Australia (Schibeci and Sweeney, 1988). Part of the survey sought respondent views about the extent to which they would like more information on a range of topics. We sought views on five particular topics: Medical problems, Health and fitness, Home maintenance problems, Swimming pool maintenance problems and gardening. All five areas were considered to be not directly related to paid employment for most adults; further, each area has a science or technology base.

The question which guided us was, For those who wanted more information on the five nominated areas, to what extent was this information available? For the majority, information was available from one source or another, although a significant minority reported that they did not have "ready access" to the information wanted: this ranged from 15.9 percent of those nominating the topic of Gardening to 25.6 percent of those nominating the topic of Medical problems (Schibeci and Sweeney, 1988). There is clearly a gap in the availability of knowledge for some adults in the community.

SEEKING SOURCES OF SCIENCE AND TECHNOLOGY INFORMATION

In the second phase of the investigation, we sought to establish the sources of science and technology information available in the Perth metropolitan area. Although most of the individual sources are specific to Perth, each metropolitan centre in Australia has, in general, an equivalent.

We decided, for convenience, to group the various sources into three categories: government/semi-government sources; private sector organisations; and, tertiary institutions. The sources are listed individually in the Appendix.

THE INFORMATION SOURCES

Methods and Procedures

Each organisation we identified as a potential information source was contacted by a telephone call, usually to the education officer or to the public relations staff. A personal interview was conducted with the appropriate representatives of most of the major sources of information.

Information from other organisations was compiled from telephone interviews and from the brochures, reports and other literature sent to us.

The opportunity to correct or amplify our report, and to request a copy of the completed report was given. The section of the report relating to each organisation was sent to the contact person with a reply-paid envelope.

Responses were used to amend (if necessary) the appropriate section of the report.

Government/Semi-grovernment Sources

We identified many information sources which were state government departments, statutory authorities or those which received substantial state government support. Among the relevant state government departments are: Agriculture, Conservation and Land Management, Education, Health, Mines and TAFE.

Some organisations have a specific 'education' mission among the organisation's functions, aimed usually (although not exclusively) at school students or adults. The Zoo, for example, has an Education Centre which caters for visits from about 11,000 students each year (a further 32,000 students visit the Zoo without using the Education Centre). For adults, the Centre provides facilities (on weekends and after hours) to nature and conservation groups. Volunteer guides (trained by Zoo staff) offer conducted tours to groups which seek them.

The W.A. Museum similarly has an education section which caters mainly for school students. However, adult groups which seek help will also be provided for: for example, volunteer guides customarily show one adult migrant group a week around the museum. Other organisations that can cater for adults are the Rottnest Island Environmental Education Centre and King's Park.

Most government departments provide 'passive' services. That is, they produce printed materials or have a library, but in general it is up to the individual to seek the information out (This situation is likely to be true across Australia). Some of these departments or authorities (such as the Environmental Protection Authority) will also provide speakers to interest clubs or groups if requested.

Sources not specific to Perth are the Australian Government's main sources of science and technology information, the C.S.I.R.O. and the A.B.C. The C.S.I.R.O. has an active education service aimed mainly at schools student, such as the 'Double Helix' science club. There are many C.S.I.R.O. publications (posters, leaflets and the like) which are available to adults as well as school students. The A.B.C. broadcasts science and technology programmes on both radio (such as the Science Show) and television (in particular, Quantum). An overview of science in the media in Perth has been published elsewhere (Hall, Schibeci, and Smith, 1988).

Private Sector Organisations

There are many sources of information which are not government or semi-government sources. Some of these are purely commercial outlets such as bookshops and plant nurseries. For keen home gardeners, plant nurseries, many of which provide informative leaflets, are an obvious source of information. Of course, few if any of those in bookshops or plant nurseries would have a background in science and technology, and may not, therefore, be able to offer explanations of the scientific or technological principles underlying the advice offered.

The SciTech Discovery Centre is one of a new breed of "hands on" science centres; it opened in August, 1988. The Centre has an active education effort directed mainly at school students. There is currently no particular effort to attract adult groups (as opposed to parents) to the Centre; however, this area is receiving attention at the time of writing.

Tertiary Institutions

Each of the four tertiary institutions offers courses of one kind or another to adults. Murdoch University and the University of Western Australia jointly offer courses through the University Extension Service. An examination of courses offered in 1987 reveals that about two percent of courses can be labelled "physical science or technology" courses. For 1988, the corresponding figure is similar (1.4 per cent). There is a much higher proportion of biological science course (in 1987, about 13 per cent, and 12 per cent in 1988). For comparison, the percentage of "computing in business" courses was 17.4 per cent in 1987 and 15.6 per cent in 1988 (Schibeci and Switzer, 1989).

It is worth mentioning here that the Australian Academy of Science proposes to develop an Australian Science and Technology Information Service. According to the information brochure it has been planned to promote public understanding of science and technology among three strategic groups, as follows: (1) The general public (via the media), (2) Secondary Schools (students with their teachers), and (3) Politicians (with their administrators). Funding is sought from the Australian Government to establish three types of services described as follows. A media referral service would put media people in direct contact with suitable experts for information and comment on scientific and technological matters. Educational services would co-ordinate personal contact between schools and active scientists and technologists. Political services would provide a directory listing of sources of science and technology information, for the use of politicians and administrators.

Issues to be Considered

A number of issues arise from a study of the sources of information listed.

One is the adequacy of provision for adults. Organisations which have an active education program generally aim at the school population. This is understandable, given the captive nature of the school student audience. There is a much less active program directed at adults. Again, this is to some extent understandable: the adult population is a more diffuse one than the school student population. Despite the difficulties, the effort to reach interested adults must be made, perhaps through a 'science and technology shop' or by building on current networks (such as flora clubs).

Another issue is the 'user pays' principle Many of the newer organisations charge admittance fees. This may be perfectly reasonable for commercial organisations. However, why is it not possible for a state such as Western Australia to be able to afford its population (especially its adult population) free access to all major sources of science and technology information? As a community, we provide a free Art Gallery and a free Museum. Why not a free Centre for Science and Technology?

A third, broader issue is the one generally labelled 'The public understanding of science'. The phrase, 'Public understanding of science', is commonly used today. Its meaning is not.

Shortland (1988) pointed out there are three elements in the phrase, none of which has a clear, unequivocal meaning. The 'public' can refer to particular groups within the general community, such as politicians or the general adult population who have left school or journalists and so on. Shortland, for his purposes, defines the public as "people as a whole, other than those acting in their professional capacity as members of representatives of the scientific community" (p.306); this general meaning is the one adopted here.

The second element of the phrase, "understanding" is also troublesome. "By understanding, do we mean a grasp of the aims of science, the norms of science, the processes of science, the products of science, or some combination of some or all of these?" (Shortland, 1988, p.312). My own view is that an understanding of the processes of science is most important for adults (and school students).

Finally, science can mean different things to different people. Shortland adopts a sociological view: "scientific knowledge is ... that particular form of knowledge in our society that is the product and bears the scale of approval of the scientific community" (p.306). In his definition are included "scientific aspects of medicine and technology" as well as the natural sciences. It is worth distinguishing here between science and technology. Science is essentially about explaining; technology is about doing. Certainly scientific understanding can improve technology (the process or the product), but it is possible to 'do technology' without a deep scientific understanding.

It's worth here to consider the general issue of why we want to promote public understanding of science and technology.

Why promote public understanding?

The reasons are many and varied. We can reduce them to two: societal and individual. The societal arguments are of various kinds, economic and cultural among them. Thus, public understanding of science leads to an improvement in the nation's economy, or the cultural life of the nation. That is, according to this argument, science benefits the community materially and morally. At an individual level, public understanding of science can lead to empowerment. The individual with this kind of understanding is better able to control his or her life, rather than being controlled by others.

Many scientists may want to promote public understanding in the expectation that understanding leads to approval. This expectation is unrealistic at best and insulting at worst. Individuals with some understanding are likely to approve of some aspects of science, but not of others. If understanding is empowering, it is naive to suppose that there is an automatic link between understanding and approval.

It is worth quoting Shortland's (1988, p.315) view of a 'scientifically literate person' here:

> It is to be empowered as the participant in a political process is empowered. It is to feel the confidence the individual feels when he or she has grasped an issue, satisfactorily solved a problem, or answered a pressing question. It is above all to be able to function effectively with matters scientific and

> technological as they arise in the course of life. It is being able to cope with science in a way that is both respectful of scientists' legitimate expertise and wary of their many fallibilities and weaknesses. It is being able to recognize science for what it is, and thus to make discerning judgements about its personal, political and social relevance. And, not least, it is ... to realise the varied character of the impact of science on society. It is to take part in scientific decision-making (or at least to be able to take part), just as lay people presently take part in political decision-making.
> In a word, to be scientifically literate is to become an active and effective citizen.

This view of the scientifically literate person leads us to consider the directions in which the current project should proceed. There are at least two questions to be considered:

(1) What is an appropriate model for adult scientific and technological literacy?

(2) How can the information provided by the various sources described above be used to help interested adults become more scientifically and technologically literate?

REFERENCES

HALL, J., SCHIBECI, R. A. and SMITH, J. (1988). Science in the media in Perth, Western Australia. Search, 19, 92-93.

Royal Society (1985). The public understanding of science. London: The Royal Society.

SCHIBECI R. A. and SWEENEY, J. (1988). Adult scientific and technological literacy: Report of a survey in Perth, Western Australia. Perth: Murdoch University.

SCHIBECI, R.A. and SWITZER, C. (1989). Sources of Science and technology information. Perth: Murdoch University.

SHORTLAND M. (1988). Advocating science: Literacy and public understanding. Impact of science on society (no. 152), 305-316.

Appendix

SOURCES OF SCIENCE AND TECHNOLOGY INFORMATION IN THE COMMUNITY

1 GOVERNMENT/SEMI-GOVERNMENT SOURCES

Perth Zoological Gardens
WA Gould League
WA Museum
Ministry of Education
Rottnest Island Authority
Technical and Further Education (TAFE)
Library Services
Kings Park and Botanic Gardens
Department of Conservation and Land Management (CALM)
Department of Agriculture
Environmental Protection Authority (EPA)
Department of Mines
Health Department
State Energy Commission of WA (SECWA)
Water Authority of WA (WAWA)
Australian Broadcasting Commission (ABC)
Commonwealth Scientific and Industrial Research Organisation (CSIRO)

2 PRIVATE SECTOR ORGANISATIONS

Underwater World
SciTech Discovery Centre
Atlantis Marine Park
The West Australian
Bookshops
Plant Nurseries

3 TERTIARY INSTITUTIONS

WA College of Advanced Education (WACAE)
Murdoch University
University Extension
University of Western Australia
Curtin University of Technology

Research in Science Education 1989, 19, 249 - 256.

INSERVICE FOR ELEMENTARY TEACHERS IN SCIENCE EDUCATION - SOME DIRECTIONS FOR THE FUTURE

A.W. Scott,

The current situation that prevails in respect to science education in N.S.W. elementary schools has stimulated an interest in inservice education and has alerted the author to the desperate need for professional development of elementary teachers in science education.

Like the situation described for Western Australia by Dynan (1983), science teaching in N.S.W. schools generally receives scant treatment and even within the 'better schools' there is often a wide range in the quality of implementation of the State's prescribed curriculum policy.

Reasons offered for this dearth elsewhere have been examined by Harlen (1985) in her book, "Teacher and Learning in Primary Science". The section, "Resistance to science at the primary level", indicates the reasons for inactivity include the low value teachers place on the subject of science, their inability to organise in the subject and their lack of self confidence when teaching the subject.

Personal findings from interviews with elementary teachers (Scott, 1988) indicate the following to be important for many who drop science to a very low priority in their programmes:

. a lack of, or unfamiliarity with physical resources;
. a lack of appropriate published activities;
. inadequate time to gather together physical resources and to organise investigatory activities;
. lack of confidence to both organise practical experiences and to teach in areas where they did not feel confident;
. lack of confidence following a lesson failure and/or a poorly received unit of work;
. unfamiliarity with requirements of the system's policy statement; and
. dislike for school based curriculum inherited when they entered on duty at their current school.

These factors result in one or more of the following: science lessons being relegated to the sessions late in the day, being "put off"; receiving little preparation time; being allocated to relief teachers; being combined with another investigatory subject such as social studies; or at worst, not being programmed at all.

Several of these points match the findings of Shrigley (1977) who found that hardware, preparation time, administrative restraints and assistance for preparation were major factors limiting science teaching for some 450 teachers in U.S.A. In Shrigley's study, skill deficiencies in the teaching of science and the placing of science as a subject below others, were lowly ranked factors related to the non-teaching of science.

Few teachers in the interviews referred to above (Scott, 1988), in contrast to the comments of Harlen (1985), identify the lack-of-importance as a reason for little science, or the fact that they were inadequately trained within their pre-service training. This of course could be a perfectly understandable stance since the Curriculum Policy Statement for N.S.W. states that science is a mandatory integral part of the curriculum and secondly, that most people are fairly proud of their training programme and the award it carries. More subtle questioning is needed to establish the validity of these claims by practising teachers.

Several teachers interviewed, suggested that they were in fact teaching Investigating Science and implementing the curriculum's philosophy, but when the content of their programme was examined, what was revealed was a course which emphasised social studies methods and concepts and not those from areas traditionally recognised as "science". Some of the older teachers suggested that another inhibiting factor was operating and that they were never given inservice at the inception of the current curriculum (**Investigating Science K-6**) or what they received amounted to a one day course and no follow-up. Consequently, many of those teachers who are actually teaching science use the pre-1980 Natural Science curriculum as a guide and disregard the philosophy of **Investigating Science K-6**.

PRESERVICE AND INSERVICE CONSIDERATIONS

What is needed is an inservice education model that encompasses the set of shortcomings, inadequacies and resistances identified above and which has a number of options to cater for individuals and their particular eccentricities and anxieties.

It would be ideal if planners could assume that some common core, upon which to base such a model, existed in the pre-service training of the current elementary teachers. It is well known however that teachers' experiences range in quantity alone from no science content or methods courses through to a substantial proportion of their training program being devoted to science. In South Australia for example, there is a compulsory minimum of 30 hours, but in England this is 70-80 hours with a suggested increase to 120 hours (Schodde, 1988). New South Wales college programs average 50.7 hours (Skamp, 1989) with slightly less in Victorian colleges (Johnson et al., 1985). An exception in Australia to the general pattern is Armidale C.A.E. which has had 120 hours for science education in B.Ed. (Infants/Primary) programs for the last 10 years.

It would also be ideal if planners could assume that all teachers were familiar with the aims and philosophy of the curriculum they are expected to implement. As noted by Brockley (1985) many teachers have "an unrealistic or distorted perception of the goals and the nature of a modern science curriculum" (pp6-7). Indeed it has been found that only one third of a group of teachers interviewed in one survey (Scott, 1988) had any ideas of the whereabouts of the Policy statement which details the current philosophy, and very few had come in contact with modern literature indicating current opinions about learning in science by children.

Consideration of the opinions expressed by teachers are generally gathered as summative evaluations of professional development conferences or inservice courses. One general opinion expressed (e.g. Dynan and Treagust, 1985) is that longer, rather than shorter (e.g. single day or single session) inservice contacts are considered to be of greater value. A second point is the high value participants of inservice education courses place on the development of teaching units. Following the first stage of an extended inservice course conducted by the author for example, 13/18 open responses to the question "Changes that participants would like to see made to this course before it is conducted again" referred to more unit preparation and planning. This same group also valued the whole and small group discussion sessions, the ideas sharing and the hand-on activities. Lectures and talks were generally not highly rated although the talk on how children learn in science was considered to be highly appropriate.

It is obvious that this particular group of teachers, on the surface at least, see inservice as a facility for preparing survival strategies for their everyday teaching. They are seeking materials suitable for immediate use in the classroom, preferably those materials which have been tried by peers.

One problem revealed by several writing groups during the unit-preparation task of the inservice course referred to above, was the inability of the teachers involved to agree on a common writing format or schedule to present their plan. Many persons were quite tied to their regularly used formats, although the newly presented ideas from the course and their implementation (e.g. use of the generative learning model), did not fit this approach. Several persons also had difficulty in adapting published resources to suit their own teaching purposes.

If single unit preparation was to be the only outcome of an inservice course, the prognosis would be dismal given the limited value of one unit in a full teaching program. However, if the skills used during the production of the unit resulted in successful lessons, then progress in professional development would be evident. At this stage of the particular continuing inservice course commented on above, there is no way to evaluate this progress. Course planners however must hope for a transfer of unit planning skills to subsequent similar events, and that teacher's classroom practices and student learning outcomes change for the better.

SOME DIRECTIONS FOR INSERVICE PLANNERS

In the light of the foregoing comments by teachers and researchers, and the points made in publications addressing inservice education (including D.E.E.T., 1988; Fensham, 1988; Warner and Lipske, 1981), several salient points need to be considered by organisers and planners of science education inservice courses for elementary teachers.

- Since there is need to allow time for participants to reflect upon and to use their new findings in the classroom, courses should be established to include a stage of review once a suitable trial time has elapsed. This practice in effect should also maintain commitment to the ethos of the course by participants.

- Support needs to be available outside the actual course setting. Head-teacher and Principal support will enable the newly found practices to be used in the school, but the teacher will also need support from peers, consultants and other experts. The development of within-and-between-school networks of teachers interested in science education should be encouraged to achieve this support.

- Participants selected for inservicing need to be willing and committed to the objectives of the course as well as their own professional development. This mechanism promotes a sense of ownership. This point can be seen as a restrictive mechanism to the dissemination of new ideas since it tends to attract those teachers who are among the more able and confident science teachers. The only hope is that participants will be influential enough to change others in the less threatening setting of the work place. Courses aimed at developing inservicing techniques and the methods by which adults learn, will naturally enhance this transmission.

- Experts and inspirational persons need to be available to impart new ideas, techniques and suggestions so that the same well used unrewarding procedures are not simply recycled, unchanged.

- Unwarranted assumptions about prior experiences in science education should not be made and it is generally necessary that leaders should be prepared at any point during a course to revisit and revise even the most fundamental issues. This includes, for example, retracing directions for tasks and clarifying seemingly simple concepts such as volume and inference.

- Hands-on, activity-based sessions should be predominant in any inservice course. When linked with clearly defined tasks which have a simple purpose, the value of these sessions is overwhelming. Lecture and talk presentations, other than the most pertinent, should be excluded with alternative modes aimed at actively involving participants taking priority.

SOME EXEMPLARY PROJECTS

SciTec

Possibly one of the most recent and ambitious projects in science inservice and professional development for teachers has been the **SciTec** project in South Australia (Crawford & Zeegers, 1988; Ian Napper pers. comm.).

This project is hopefully one answer to the calls for the on-going education of teachers (e.g. Board of Teacher Education 1987; Coulter and Ingvarson 1984) particularly in elementary science education. Not only does this project put into action most of the points considered above as good practice for inservice courses, but the State system has seen fit to support the project financially with enough funds to see its successful implementation. **SciTec** seems to be a well structured project which should eventually reach the majority of teachers throughout the State through a teacher-teach-teacher model.

Initiative 5.4

Initiative 5.4 is a project being conducted in Victoria to provide school consultants, currently working out of the Regional Resource Centres, with improved techniques for practising their inservicing tasks. The consultants are being taught by modelling teaching procedures with the 5.4 team making extensive use of ideas presented in Owen et al., 1988 (Jenni Livingston, pers. comm.).

PECSTEP

The Primary and Early Childhood Science and Technology Education Project is being conducted by Canberra C.A.E. and its prime purpose is to improve teaching and learning by increasing the effectiveness of science educators. Using materials from the **Learning in Science Project** (originating from the University of Waikato, N.Z.), the project currently involves 70 selected primary and early childhood teachers within a year long part-time course (Margaret Bearlin, pers. comm.).

CONCLUSION

It has been demonstrated that a range of factors contribute to the low status attributed by teachers to science education in many elementary school settings. The solution to this crisis is being sought by several education systems in Australia and the effective inservice/professional development models adopted invariably consider teachers as interested adult learners as they partake in extended courses. Furthermore, the models include content on the ways children learn in science, and aid in the development of teaching activities and units appropriate to the curriculum under which the participants operate.

REFERENCES

BOARD OF TEACHER EDUCATION (1987). Project 21 teachers for the Twenty First Century. Board of Teacher Education, Queensland.

BROCKLEY, B.P. (1985). The Structure and Evaluation of a Primary Science Teaching Education Program. In Owen, J.M., Johnson, N.J. & Welsh, R.J. Primary Concerns. Centre for Program Evaluation, Melbourne, C.A.E.

COULTER, F. & INGVARSON, L. (1984). Professional Development of Schooling: Rules and Responsibilities. A Report of the Commonwealth School Commission, Canberra.

CRAWFORD, G. & ZEEGERS, Y. (1988). SciTec Project - Inservice in Primary Science and Technology. SASTA Journal. **88**(3), 21-33.

D.E.E.T. (Department of Employment Education and Training) (1988). Teachers' Learning. The Report of the Inservice Teacher Education Project. Canberra, AGPS.

DYNAN, M. & TREAGUST, D. (1985). Activities? Views of CONASTA '84 Participants. Australian Science Teachers Journal. **31**(2), 41-44.

FENSHAM, P.J. (1988). Theory in Practice: How to assist science teachers to teach constructively. Paper given at AARE conference Armidale, 1988.

HARLEN, W. (1985). Teaching and Learning in Primary Science. London, Harper and Row.

INVESTIGATING SCIENCE K-6 (1980). Curriculum Policy Statement. N.S.W. Department of Education.

JOHNSON, N.J., OWEN, J.M. & WELSH, R.J. (1985). Structure of Programs. In Owen, J.M., Johnson, N.J. & Welsh, R.J. Primary Concerns. Centre for Program Evaluation. Melbourne C.A.E.

OWEN, J., JOHNSON, N., CLARKE, D., LOVITT, C. & MORONY, W. (1988). MCTP Professional Development Package. Guidelines for Consultants and Curriculum Leaders. Canberra, C.D.C.

SCHODDE, P. (1988). The Preparation of Science Teachers. SASTA Journal. **88**(3), 48-49.

SCOTT, A.W. (1988). Effectiveness of pre-service science courses at A.C.A.E. Report to the Research Committee. A.C.A.E. Armidale.

SHRIGLEY, R.L. (1977). The function of professional reinforcement in supporting a more positive attitude of elementary teachers towards science. Journal of Research in Science Teaching. **14**(4), 603-616.

267

SKAMP, K. (1988). Preservice primary education in N.S.W.: a comparative analysis of imposed science education curricula. Research in Science Education. **18** 71-82.

WARNER, D. & LIPSKE, I. (1981). Towards a Systematic Approach to Inservice Education for Teachers. Unicorn. 7(2), 180-190.

Research in Science Education 1989, 19, 257 - 267

GENERAL SCIENCE KNOWLEDGE AND ATTITUDES TOWARDS SCIENCE AND SCIENCE TEACHING OF PRESERVICE PRIMARY TEACHERS: IMPLICATIONS FOR PRESERVICE SCIENCE UNITS

Keith Skamp

INTRODUCTION

The recent Discipline Review of Teacher Education in Science (DEET,1989) drew the distinction between discipline studies (the study of science as such) and pedagogical studies (the study of teaching and learning and their interrelationship). It implied that inclusion of the former in preservice teacher education programmes would build primary teachers' confidence in science(p.37). This was partly premised on a knowledge of the secondary science background of preservice primary teachers. This paper addresses the issue of the confidence to teach science of preservice primary teachers and poses questions about the relationships between that 'confidence' and the types of students and the preservice science units they complete.

The study involved measuring the general science knowledge and attitudes towards science (ATS) and science teaching (ATTPS) of preservice primary teachers and students entering a science degree. Changes in the attitude scores were determined at the end of semester 1 when the preservice primary teachers had finished a science pedagogical unit and the science students several science discipline studies. The science students were therefore an interesting control comparison group used to validate the effects of the science education unit on the attitude scores(permitting a pretest-posttest control group design).

Reference to 'confidence' data (MacLeod,1988,1989) suggests that the relationship between discipline studies, attitudes towards science and science teaching, and confidence to teach science may not be straightforward. Further the influence of mode of entry, sex and secondary science background on the attitude and knowledge scores indicates that mature age students (especially women), despite lower science entry scores on the measures used, appear to develop more positive attitudes towards science teaching.

The inclusion of the science control group, the reporting of subscale attitude results and the influence of various student variables on the knowledge and attitude scores distinguishes this study from earlier work on attitudes(Dooley & Lucas, 1981; Ginns & Foster, 1978) and science knowledge of preservice primary teachers(Kings,c.1968). The implications for preservice primary science teacher education are especially relevant in the context of the recent Discipline Review.

PROCEDURE

Commencing students in the the Bachelor of Education (Primary) [BEd] and Bachelor of Applied Science [BApplSc] at Northern Rivers College of Advanced Education were surveyed during the first week of lectures in 1988 and 1989. The first cohort's ATS and ATTPS scores were measured using Moore & Sutman's (1970) and Moore's (1973) instruments respectively. Both measures were reapplied in the last week of lectures in the first semester. The second cohort's (commencing students in the two degrees in the following year) general science knowledge was ascertained using the General Science Test 2M (consisting of multiple choice year 5 and 12 anchor items) compiled by the Second International Science Study (SISS)(Payne & Rosier, 1988).

Students in both degree programs undertook four units in their first semester: BEd -Educational Studies I, Practicum I, and two Curriculum Studies units [including a science pedagogical study (0.5 of a unit)-for a description see Skamp (1987)] ; and BAppSc- Biology, Chemistry, Geology and Resource Assessment Techniques I.

The secondary science background of the students in the two degree programmes in the two consecutive years indicated that differences were not marked in 1988 (Two HSC science subjects completed : science (S) 23.2%; education (E) 11.6%; one HSC science subject: S63.9; E66.4.; SC (school certificate) science (or less): S9.3; E17.8). In 1989 the science degree students had a generally better secondary science background, viz, Two HSC science subjects: S 33.3; E 13.1.; one HSC science subject: S 50.8; E 67.2; SC science subject (or less): S 5.9; E 15.5. (See Note 1).

Both degrees take in mature age students and other non-school leavers. In 1988, 24 percent of enrolments in both degrees were mature-age; in 1989 the percentage of non-school leavers was 17 (E) and 33 (S). There is a contrast in the sex balance in the two degrees [E Female: 80.8 (1988); 72.1 (1989); S Female: 32.4 (1988); 31.4(1989)].

RESULTS AND DISCUSSION

Attitudes towards science and science teaching

Before discussing the results and interpretation of the ATS and ATTPS scores it should be noted that the scales were constructed in the early seventies and the attitudes expressed towards science and science teaching reflected that period. Apart from where indicated however the position statements representing science and science teaching attitudes would still be valid today.

Overall scores.

Comparison with earlier Australian studies (see p.258) indicates that over a ten-year period students entering teacher education programmes have shown little variation in their commencing attitudes towards science and science teaching. The results (see Table 1) show that students entering both degree programmes have very slightly positive attitudes towards science and a neutral attitude towards teaching primary science. On completion of their first semester units the ATS scores for both groups did not change significantly. However education students' ATTPS scores improved significantly (and substantially) , whereas science students' attitudes towards teaching primary science did not significantly alter. [It is interesting to note that ATTPS scores-for education students- may be higher at the completion of semester 4 (see results in Skamp,1988b, and Dooley & Lucas,1981), but are still low compared to Moore's (1973) reported scores]

TABLE 1
DESCRIPTIVE STATISTICS AND t-TESTS FOR PRE- AND POST-COURSE SCORES ON ATS AND ATTPS SCALES
(Unpaired Subjects)

School	(n)	Pre-Course mean	Pre-Course S.D.		Post-Course mean	Post-Course S.D.	Difference	t	(p)
Scale : ATS		(maximum score = 120)							
Education	(151)	74.29	8.30	(107)	75.87	10.41	1.58	1.34	(0.18)
Applied Sc.	(109)	76.62	9.23	(69)	77.77	8.64	1.15	0.92	(0.41)
Difference		2.32**			1.90				
Scale : ATTPS		(Maximum score = 90)							
Education	(151)	49.19	6.85	(107)	57.84	11.41	8.65**	7.55	(0.001)
Applied Sc.	(109)	47.99	5.19	(69)	48.71	6.25	0.72	0.86	(0.40)
Difference		-1.20			-9.13**				

** Significant at ≤ 0.05 level (Fisher PLSD and Scheffe F - test).

A multiple regression analysis using the pretest results for the ATTPS scale as the initial predictor variable and the degree programme as the second predictor variable (i.e. an analysis of covariance in order to isolate the effect of the treatment) indicated that these two variables and their interaction accounted for 31 percent of the variance in the post ATTPS results (df = 142; F = 32.9). Of this variance, 25 percent was attributable to the interaction of the pretest with the treatment (df = 142; F = 48.2). This supports the interpretation that the curriculum studies unit is a significant factor associated with the change in the education students' attitudes towards primary science teaching.

An interesting comparison can be made between ATTPS scores and MacLeod's (1988, 1989) data which determined the (self-rated) confidence to teach science of students in the B.Ed. (primary) programme (see Table 2.) As students progress through their programme (and their Semester 1 and 4 science curriculum units) the percentage of students feeling totally or reasonably confident increases. This is paralleled by an increase in the percentage of students obtaining better than mildly positive ATTPS scores, and would support the interpretation that a more positive attitude towards teaching primary science is associated with a greater self-confidence. The latter has been related to more effective practice (Bonnstetter & Yager, 1985).

TABLE 2
COMPARISON OF ATTPS SCORES WITH CONFIDENCE TO TEACH SCIENCE

	ATTPS Scores[1]		Confidence to Teach Science[2]	
	≤30	≥60	Somewhat/ Totally Uncertain	Totally/ Reasonably Certain
	(percentage responses)		(percentage responses)	
1988 Cohort				
on entry	0.7	8.4	41.2	20.6
end Semester 1	2.9	47.1	–	–
beginning Semester 3	–	–	25.7	38.7
1986 Cohort				
Semester 4	0.0	72.0	–	–
Beginning Semester 5	–	–	10.7	63.7

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[1] ATTPS scores of 30 or less are mildly to strongly negative while scores of 60 or more are mildly to strongly positive (possible range 0-90).

[2] These figures are from MacLeod's (1988, 1989) data which asked students to express their "degree of confidence in applying effective methods of teaching science."

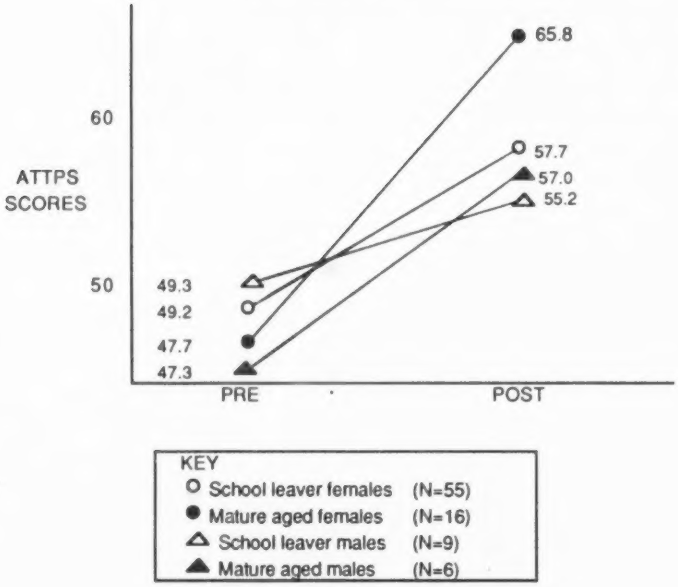
Analyses for subgroup differences (on the ATTPS scale) within the education cohort suggest that although students with HSC science enter college with slightly more positive ATTPS scores than those with only SC science, this difference is no longer present at the end of the semester. No other differences (due to sex or mode of entry) are present on entry, but by the end of the semester female students have significantly higher ATTPS scores than males and (at the 0.06 level [t-test]) mature age students (most of whom are female) score more positively than school leavers. A stepwise regression analysis with the post-ATTPS scores as the dependent variable and the independent (predictor) variables being the pre-ATTPS scores, sex, mode of entry and their interaction effects enters the interaction effect of the sex, entry mode and pre-ATTPS scores first (16 percent of the variance; df = 85, F = 16.63, $p < 0.05$) and the sex-mode of entry interaction second (accounting for a further 9 percent of the variance, df = 85, F = 14.64, $p < 0.05$). Comparison of the scores of the subgroups suggests that mature age females are scoring higher than other groups on this scale as a result of the science curriculum unit (see Figure 1).

Subscale results

The science attitude scale consists of four subscales (each associated with a positive and negative position statement). With minor exceptions (see note 1) the scores on the subscales do not significantly differ for students in either degree on entry or at the conclusion of the semester . Both groups of students held views which were consistent with a mildly positive attitude towards science on the position statements. It is worth noting that at the end of the semester education students significantly disagreed with the statement 'The laws and/or theories of science represent unchangeable truths discovered through science' compared to their entry views.

Analysis of the subscales of the ATTPS instrument shows that education students entered college slightly more favourably oriented towards emphasising science processes than science students (but believing more strongly that certain science facts should be taught to primary age children). Education students also felt more strongly that teachers should be facilitators. In other ways both groups were similar on entry: they were

FIGURE 1
SUBGROUP SCORES ON THE ATTPS SCALE
(Pre and Post measures)



ambivalent about their understanding of science and desire to teach it (although they disagreed with the idea of not wanting to teach science); both groups also tended to agree with teachers telling students what they have to learn. On completion of the first semester education students had shown statistically significant improvements on all sub-scales apart from the position statement "I do not like the thought of teaching science," with which they still mildly disagreed. Science students showed no significant changes(See Note 1). The subscale analysis suggested that some perceptions of the role of the subject and the teacher can change relatively quickly but underlying feelings about ability to teach science seem difficult to change. [One of the more "negative "atittudes (students' perceptions that science facts are important for children to know) may be partly explained by changes in emphasis in science education since the early seventies(see Note 2)]

General science knowledge

On entry education students scores were significantly lower ($F = 34.38$; $p = 0.0001$) than science students. Their results are compared with NSW 14 year olds and year 12 students (Payne & Rosier, 1988) in Table 3. Kings (c. 1988) found that first year primary teacher education students scored 52.3 percent (S.D. 4.33) on a 30-item SISS Year 12 test.

TABLE 3
MEAN PERCENTAGE SCORES BY PROGRAMME AND FOR NSW 14-YEAR-OLD STUDENTS AND YEAR 12 SCIENCE STUDENTS

Group	Test Total (30 Items)	Year 5 Anchor Test (15 Items)	Year 12 Anchor Test (15 Items)
Science (n = 50)	81.1 %	88..3 %	73.9 %
Education (n = 123)	69.1 %	81.3 %	56.9 %
NSW 14-year-old students (N =787)	58.9 %	72.3 %	45.5 %
NSW Year 12 science students (n=896)			65.9 %

BEd students performed significantly better if they had completed a physical science (mean,23.56;SD,4.13;n=16) compared to a biological science (21.05; 3.19;n=61) at HSC level. Both these groups outperformed students who had HSC general science (19.05;3.23;n=21) or school certificate science [or less] (19.25;4.59;n=24). The latter two categories did not significantly differ.

Analysis of variance results, for education students only, found significant main and interaction effects when sex and secondary science background were used as the independent variables. Males performed better than females irrespective of secondary science background. (This result was also irrespective of the degree programme.) Item analyses indicate that physical science items and those requiring comprehension and application of science concepts cause the most difficulty for education students (see Note 1).

DISCUSSION AND CONCLUSIONS

Teachers will teach better if they have a sound knowledge of their subject-a truism often overlooked (Shulman,1986). Dobey & Schafer (1984) found that when preservice primary teachers had an "intermediate" science knowledge about a topic they taught more effective inquiry oriented science. The results reported here highlight that commencing preservice primary teachers do not have a strong general science background (particularly in the physical sciences). As very few preservice programmes have compulsory science discipline studies, and science pedagogical studies comprise only about 4.5% of such programmes (Skamp,1988a; Owen et al., 1985), then serious consideration needs to be given to ways to address this issue (DEET, 1989). However solutions are not obvious . This study further supports earlier work that pedagogical studies improve attitudes towards science teaching (and probably confidence) but that "traditional" discipline studies do not improve attitudes. Perhaps an improved knowledge of science and more positive attitudes towards science could be developed if units which highlighted the syntactical and substantive structure of science (as distinct from isolated science concepts and their application) were included in preservice programmes. Shulman supports this assertion (p.9) (with secondary teachers in mind), and although it is acknowledged that primary teachers may not need the depth of conceptual knowledge of the secondary teacher some understanding of the syntactical and substantive structure of science would greatly assist primary teachers help children perform comparing, pattern-finding, hypothesis generation and question raising investigations as suggested by Harlen(1985). Some support for emphasising the syntactical strucure of science is found in the current study (see p. 5) where it was determined that the preservice teachers changed their views about the tentativeness of scientific laws/theories (an aspect emphasised in the science curriculum unit).

That attitudes towards primary science teaching are improved by continued exposure to science pedagogical studies is an anticipated result with obvious implications. A not so obvious result is the way particular subgroups are affected differently by the science education unit. Women enter the programme with similar ATTPS scores and lower general science knowledge scores than males, but after completion of the science education unit mature age women have significantly higher scores on the attitude towards science teaching scale. That this subgroup (apparently irrespective of secondary science background and science knowledge) has developed far more positive attitudes warrants further investigation. It also indicates that more consideration could be given to increasing the mature age intake into primary teacher education.

Practical solutions to achieving an improved science background knowledge and more positive attitudes towards science and science teaching are difficult to prescribe because of the uncertain relationships between the type of science studies taken and their influence on students' attitudes towards science and science teaching (as measured by the instruments in this study). Further the inference that students with the poorest knowledge background (females and especially mature age females) develop the most positive attitudes is a dilemma. Some suggestions for future testing have been made but whether they can be successful within the current constraints of teacher education programmes is problematic. The effect of the implementation of the recommendations of the Discipline Review as they relate to these questions will be interesing to investigate in the light of this study.

Acknowledgements

The assistance of Dr. Gordon MacLeod in the analysis and Ms. Sue Sawkins in the organization and processing of the data is acknowledged as is the cooperation of Mr. Murray Cullen from the School of Applied Science, and Dr. Malcolm Rosier from ACER.

Notes

NOTE 1: The following details may be obtained from the author: ANOVA results for the gain scores on the ATS and ATTPS scales using the degree programme as the independent variable; group (science and education) scores on the ATS and ATTPS subscales; item analyses on the SISS 2M test.

NOTE 2: In the early seventies there was an overt emphasis on science processes and a de-emphasis on science products. Students in the current study are not presented with this dichotomy, but rather are encouraged to see the relationships between concept and process skill development. In fact the development of processes is seen as of equal (but interdependent) importance to the development of concepts. A further and related difficulty could be that students in the first year of their degree are still clarifying the difference between children "developing concepts" and "knowing facts." [Skamp's (1988b) study tends to support this.].

REFERENCES

BONNSTETTER, R. J. & YAGER, R. E. (1985). A profile of excellence: Teachers of exemplary programs in elementary science. Journal of Teacher Education, 22 (8), 45-46.

DEPARTMENT OF EMPLOYMENT,EDUCATION AND TRAINING.(1989). Discipline Review of Teacher Education in Mathematics and Science.,Vol.1. Canberra, AGPS.

DOBEY, D. C. & SCHAFER, L. E. (1984). The effects of knowledge on elementary science inquiry teaching. Science Education, 68 (1), 39-51.

DOOLEY, J. H. & LUCAS, K. B. (1981). Attitudes of student primary teachers towards science and science teaching. Australian Science Teachers Journal, 27 (1), 77-80.

GINNS, I. S. & FOSTER, W. J. (1978). A comparison of teaching strategies and their effect on attitudes to and understanding of science. The South Pacific Journal of Teacher Education, 6 (2), 154-158.

HARLEN, W. (1985) Teaching and learning primary science. London, Harper & Row.

KINGS, C. B. (c. 1988). Sex and science backgrounds of trainee teachers. Unpublished paper, Victoria College, Melbourne, 11 pp.

MACLEOD, G. (1988). Unpublished data. Lismore, Centre for Research on Teacher Education and Development, Northern Rivers C.A.E., 149 pp.

MACLEOD, G. (1989). A study of graduating students from ten diploma of teaching programmes in New South Wales. Lismore, Centre for Research on Teacher Education and Development, Northern Rivers C.A.E..

MOORE, R. W. & SUTMAN, F. X. (1970). The development, field test and validation of an inventory of scientific attitudes. Journal of Research in Science Teaching, 7, 85-94.

MOORE, R. W. (1973). The development, field test and validation of scales to assess teachers' attitudes towards teaching elementary school science. Science Education, 57 (3), 271-278.

OWEN, J. M., JOHNSON, N. J., & WELSH (1985). Primary Concerns. Melbourne, Melbourne College of Advanced Education, Commonwealth Tertiary Education Commission.

SHULMAN, L. S. (1986). Those who understand knowledge growth in teaching. Educational Researcher, February, 4-14.

SKAMP, K. R. (December, 1987). Evaluating a teacher education course: A case study (preservice primary science teacher education). Paper presented at the AARE/NZARE Conference, Christchurch, New Zealand, 21 pp.

SKAMP, K. R. (1988a). Preservice primary teacher education in NSW: A comparative analysis of espoused science education curricula. Research in Science Education, 18, 71-82.

SKAMP, K. R. (1988b). Evaluation of science curriculum units. Unpublished report, Northern Rivers C.A.E., Lismore, 11 pp.

Research in Science Education 1989, 19, 268 - 277.

SOME CLASSROOM APPLICATIONS OF CURRENT IDEAS ON CONCEPTUAL LEARNING IN SCIENCE

Beverley Stanbridge

INTRODUCTION

Meaningful learning can be considered to be the desired outcome of any teaching activity. The following simplistic model (Fig. 1) may be used to show how this learning takes place.

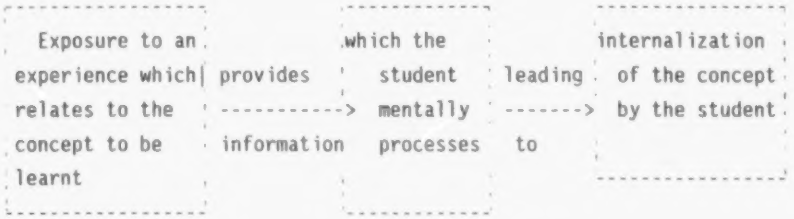

Exposure to an experience which relates to the concept to be learnt
provides information
which the student mentally processes
leading to
internalization of the concept by the student

Fig. 1 - The steps involved in meaningful learning

Shayer (1989) maintains that if the learning tasks involve processing skills beyond the current cognitive stage of development of the learner, then meaningful learning will not occur. Thus principles a scientist would consider to be basic to the discipline may only be cognitively accessible to about 30% of the present generation of Junior High School students (Shayer 1989).

Shayer (1989) suggests that the early years of high school education would be best spent in activities which accelerate intellectual growth to a point where more cognitively demanding concepts can be processed.

This study evaluates the use of the constructivists' approach to teaching as a metacognitive tool for accelerating intellectual growth.

BACKGROUND

There are numerous reports (Osborne & Gilbert (1980); Gilbert et al., 1982; Driver and Erickson, 1983) concerning the "alternative frameworks" approach to the learning in science. Here students' constructs are explored by the teacher, and then remoulded into, or superceded by the actual scientific concept. This study is concerned that some students may not be able to make sense of the procedures whereby the scientific concept is justified to the student. It is felt that the student's involvement in constructing, evaluating and modifying ideas is far more educationally valuable than the acquisition of the concept itself. The fact that the internalized concept does not reflect the sophistication of the scientific version should not cause undue concern.

The approach used in this study was derived from Driver and Oldham's (1986) constructivist teaching sequence. The pathway for this approach (Fig. 2) accommodates the meaningful learning model(Fig. 1), modifying it to allow processing of experiences to occur at different levels of cognitive sophistication.

The term "scientifically acceptable" needs qualification. Given that students are performing processing operations at different levels, it follows that a variety of constructs will evolve. Any construct which could not be convincingly falsified by the class was considered to be "scientifically acceptable". Many of the ideas which were accepted would not meet the requirements of a text book definition, but they provided us with an adequate basis with which we could talk science to each other, and use these ideas to define other concepts. The intended outcome was that the students owned the constructs: their version of the concept had been internalized and therefore meaningfully learnt. Rogers (1969) uses the term "learner based learning" to describe this interaction. The outcome being the acquisition of private knowledge rather than teacher-imposed public knowledge.

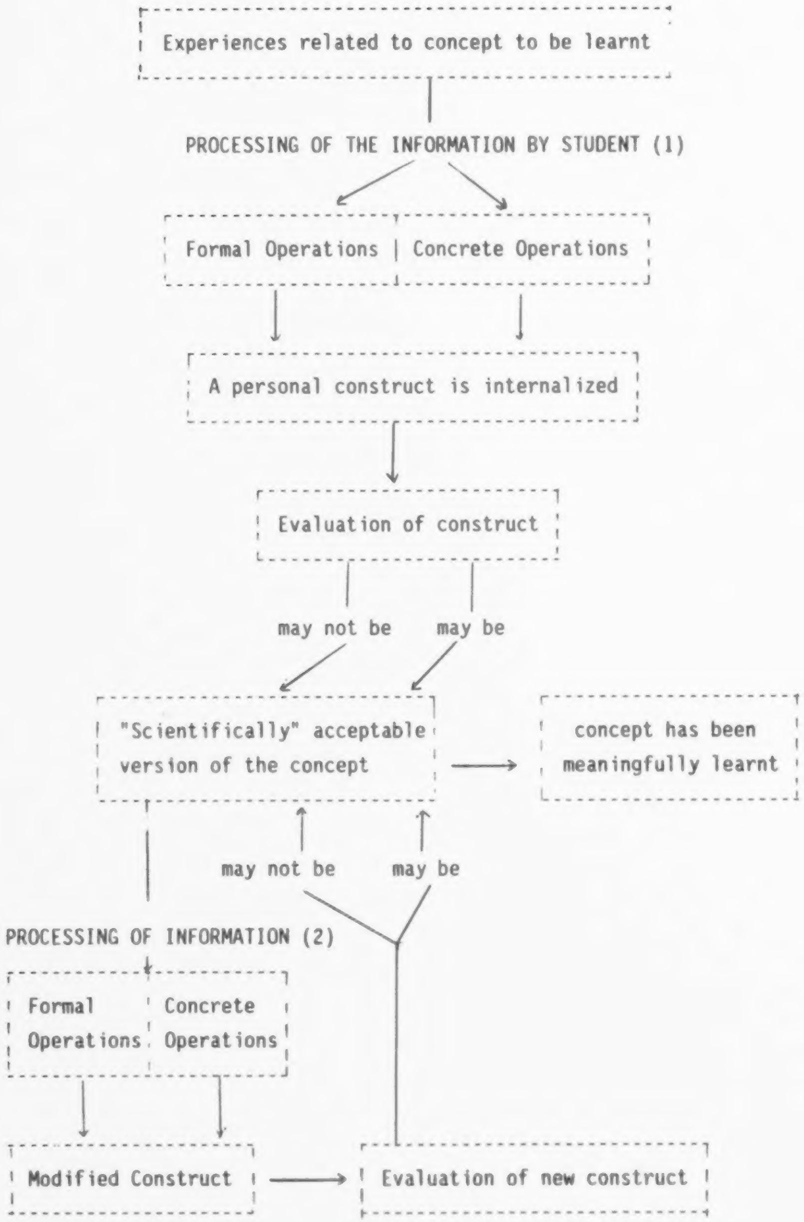

Experiences related to concept to be learnt
PROCESSING OF THE INFORMATION BY STUDENT (1)
Formal Operations
Concrete Operations
A personal construct is internalized
Evaluation of construct
may not be
may be
"Scientifically" acceptable version of the concept
concept has been meaningfully learnt
may not be
may be
PROCESSING OF INFORMATION (2)
Formal Operations
Concrete Operations
Modified Construct
Evaluation of new construct

Fig. 2 - A procedural pathway to meaningful learning

The metacognitive aspects of this study lie in the processing and evaluation areas of the pathway (Fig. 2). Solomon (1986) suggests that students' explanations of events (constructs) fall into modes, ranging in sophistication from tautological redescriptions, through casual relationships to those which distance themselves from the event by reference to another domain (for example analogies and metaphorical models). Students operating at the concrete level work in the same domain as the event; metaphorical explanations are usually constructed by formal level students.

The evaluation process however can involve students at all levels of thinking. At the lowest level of sophistication an idea is O.K. provided it "makes sense". Students operating at the concrete level of thinking tend not to generalise, and may not appreciate the more hypothetical challenges made to ideas, i.e. if an idea explains the case in point it is good enough.

From what has been said it may appear that students operating at the early and middle range of thinking may have limited inputs to make. This has tended not to be the case - the dynamics of the learning sequences described through student-student, group and whole class interactions can draw the less able students into the metacognitive processes. Working at their own pace and in a less public and non-threatening environment, they are willing to "have a go". All contributions must be seen as being valuable and appropriate. Lower ability students begin to experience some measure of success which leads to greater self-confidence to have "more of a go". By this stage students are actively thinking about and processing ideas.

In order to assess intellectual growth, the cognitive stage of the learner needs to be identified prior to and at the conclusion of the study. As pointed out by Biggs and Collis (1982) cognitive level of development and cognitive level of performance may not be synonymous. The latter is influenced by student attitudes towards variables such as peers, teacher, the content of the work and self-esteem, amongst others. Whilst the cognitive level of performance cannot exceed the level of development, it may fall below it, and indeed may fluctuate in accordance with student attitudes. Attempts were made to control the above variables during the study - since peers, teacher and content did not change. Self-esteem was closely monitored. It could then be considered that any sustained increase in cognitive level of performance would indicate a gain in cognitive level of development.

THE STUDY

The teaching sequence (Fig. 2) was used consistently during a ten week Electricity Unit taught to three grade 9 classes of mixed ability and gender.

The cognitive level of development of the students was measured using the Understanding in Science Test (Tisher and Dale 1975). The cognitive level of performance was identified from the teacher's previous experience of working with these students. There was a good correlation between these levels for the majority of students.

Classroom Management

Students worked in pairs, groups of four or as a whole class. The experiences which required the construction of explanations were either experimental or demonstration work. Both were kept as simple as possible. Experimental work was performed in pairs. Students would then try to construct ideas together. These would then be shared with the other members of their group of four. Preliminary evaluations would enable a "group idea" to be arrived at. Group or individual constructs were then shared with the rest of the class, for further evaluation. Any criticisms had to be substantiated.

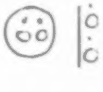
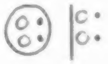
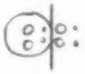
The role of the teacher was critical at this point. Domination of discussions would deter many "would be ideas" for fear of getting the "wrong answers". At the same time a democratic atmosphere needed to be maintained, in order to prevent any one student or group monopolising the interactions. The teacher's main role was to ascertain the exact meanings students ascribed to their constructs. In order to do this students were asked to draw their ideas on an O.H.P. transparency, or the teacher drew them in front of the class as the students described their ideas.

Where challenges to ideas implied further testing, a demonstration experiment was set up on the spot, usually by the students concerned.

Finally a class-owned idea had to be distilled from the group ideas which had not been invalidated. It was essential that this selection and often amalgamation of ideas was done by student consensus, not by the teacher.

An Illustrative Example

Constructs to explain why a balloon when rubbed on a woollen jumper, is drawn to and sticks to the jumper for a short while before falling off. These constructs clearly fall into Solomon's modes of explanation as outlined on Page 271.

	STUDENTS' IDEAS		STUDENTS' CRITICISMS
1.	The hairs on the jumper rub off onto the balloon. When the balloon is held near the jumper the 2 sets of hairs entwine. Then the weight of the balloon gets too much and the hairs pull apart.	1. 2.	But why is the balloon ATTRACTED to the jumper? The balloon can't just get heavier.
2.	It's like a magnet. Rubbing causes the domains in the balloon to point one way making way a North Pole. The jumper's domains point the other way making a South Pole. Opposite poles attract.	1. 2. 3.	What happens if you rub the balloon up and down on the jumper and not just stroke it? Why does the balloon fall off? How is it demagnetised? You can only make magnets out of metals.
3.	The balloon and jumper both have equal numbers of sorts of opposite things on them. (Fig.)  When you rub, the opposites get drawn to one surface or the other. i.e.(Fig.)  Now opposites want to stick together. (Fig.) 	1. 2. 3.	Why does the balloon fall off? Answer - the weight of the balloon is too great for the opposites to hold it there. Where do these opposites come from? Why do balloons and jumper end up with 2 kinds of things - why not just : or $\overset{\circ}{\circ}$?

4.	The balloon gets hot due to friction from rubbing. The plastic gets sticky as it melts a bit, so the balloon sticks to the jumper.	1.	Why does the balloon fall off? Answer - as it cools the balloon loses its stickiness.
		2.	Why does the balloon get attracted to the jumper? Answer - heat attracts things. General disbelief at this statement and many illustrations to the contrary!
5.	Rubbing makes "things" (drawn as a * on the edge of the of the jumper) form on the jumper. The balloon wants some too so it is drawn to the jumper. The balloon steals the * off the jumper. The jumper wants them back - so won't let go of the balloon. When it gets them back the jumper lets go of the balloon.	1.	How does rubbing actually make these *s?
		2.	What happens to the *s after the balloon falls off? If they stay on the jumper the balloon should stick again without rubbing.
		3.	Why does the balloon want these *s?
6.	It's due to static electricity	1.	What does this mean? Answer - We don't know.

None of these ideas were "fool-proof", so a second demonstration was set up. Students had to use their ideas to predict what would happen if two balloons were rubbed on the same jumper, removed and then held near to each other. A demonstration was then conducted. Where predictions were inaccurate, students had to attempt to modify their constructs.

Owners of ideas 1 and 4 could not modify their ideas - hence these ideas were abandoned with the consent of their inventors. Owners of idea 2 assumed each balloon to have similar poles, which repel each other. Owners of idea 3 decided that each balloon would have to have had the same kind of "things" on their surfaces - and similar "things" repel. Idea 5 was modified slightly so that once the balloons had stolen the *s, they no longer wanted them but wished to return them to the jumper. Thus the balloons kept out of each others way in case either off-loaded unwanted *s on the other.

The class chose ideas 3 and 5 as being the most acceptable. The teacher could then attach the labels "charges" to the *s,and + and - charges to the O and .s. The constructs were then amalgamated and ascribed the name static electricity. Even so questions such as 'Where did the charges come from?', and 'Why does only one type of charge get transferred during rubbing?' were not readily answerable.

Students were given a number of test items to identify how well they understood ideas of charge and charge transfers. Students went over tests together analysing and modifying answers. They discussed any aspects of the class constructs about which they still felt unsure. Retesting showed most students had a very good understanding as to why objects became charged, and would attract or repel each other. These ideas were subsequently used to construct explanations as to how a Daniel cell works.

EVALUATION

Evaluation can only be very tentative at this stage since a much more prolonged exposure of students to these activities is obviously required. However some fairly significant outcomes can be identified.

A very apparent change occurred in student attitudes towards their work. Those who previously showed little interest became actively involved in the learning processes. Students grew in confidence of their ability to manipulate and mould ideas into a form they could more readily understand. Discussions and inventions of ideas would sometimes extend to out of class time. Students experiencing difficulties would get together and actively seek help from the teacher.

Has this approach advanced intellectual growth in students? One could begin by asking if meaningful learning had taken place - since this implies successful processing of experiences at the required level of mental operations.

Informal observations of student participation indicated that they did have a good grasp of the concepts. They were able to communicate ideas in their own words, at their own level of sophistication. New concepts could be defined in terms of existing ones. Low ability students felt confident to conduct conversations in terms of their constructs. Rote learning rarely ever occurred; students felt free to admit to not really understanding something. One of the more noticeable outcomes was students' willingness to ask questions. These perceptions of student behaviour were felt to have demonstrated that meaningful learning had occurrred.

Diagnostic tests administered during the units and major tests at the end, used both content and process items. Lower ability students achieved content scores often far in excess of those recorded in previous units. There was however a sizeable difference between their content and process scores. The gap tended to narrow as one moved up the ability range. Students had improved their ability to internalise concepts, but not necessarily in their ability to construct them for themselves. However it would appear that scientific knowledge had been made accessible to the majority of students, albeit in a somewhat colloquial form.

Students' responses to the test items were analysed using Biggs and Collis (1975) SOLO Taxonomy. These responses could be translated into cognitive performance level categories - and then compared with performance levels prior to doing the unit. It was found that amongst students operating at the lower level of cognitive ability there was a 57% increase in performance level. A 41% rise occurred amongst students operating at the middle concrete range. Only one out of the six students operating at the late concrete level moved to the formal level of performance.

Three possible explanations can be advanced for these rises in cognitive performance level -

1. Students had experienced a growth in their level of cognitive development - and could now process experiences at a higher level of sophistication.
2. Improved student attitudes towards their work had led to a higher level of cognitive performance.
3. Constructs had colloquialised the concepts to an extent that processing of most experiences could occur at a lower level of operation - i.e. abstract concepts requiring a more formal level of processing had now been "concretised".

CONCLUSION

Evidence collected so far seems to substantiate the contention that the constructivist approach to teaching has assisted students in their ability to interact with and internalize scientific concepts. The meanings attached to these concepts has become personalized in accordance with the learner's level of cognitive development. The question of intellectual growth is less decisive in the absence of more extensive long term studies.

From the teaching point of view this method is both interesting and rewarding, providing an opportunity to reflect on and evaluate a personalized construct for conceptual learning.

REFERENCES

BIGGS, J.B. & COLLIS, K.F. (1982). Evaluating the quality of learning. The SOLO Taxomony. (Structure of the Observed Learning Outcome). Academic Press.

DRIVER, R. & ERICKSON, G. (1983). Theories in action: Some theoretical and empirical issues in the study of students' conceptual frameworks in science. Studies in Science Education 10, 37-60.

DRIVER, R. & OLDHAM, V. (1986). A Constructivist Approach to Curriculum Development in Science. Studies in Science Education, 13, 105-122.

GILBERT, J.K., OSBORNE, R.J. & FENSHAM, P.J. (1982). Children's science and its consequences for teaching. Science Education, 66(4) 623-633.

OSBORNE, R.J. & GILBERT, J.K. (1980). A technique for exploring students' views of the world. Physics Education, 15(6), 376 - 379.

ROGERS, C. (1969). Freedom to Learn. Columbus, OH: Merrill.

SHAYER, M. (1989). Personal Communication.

SOLOMON, J. (1986). Children's Explanations. Oxford Review of Education, 12, 41-51.

TISHER, R.P. & DALE, L.G. (1978). The Understanding in Science Test. A.C.E.R. Publication. 18, 71-82.

Research in Science Education, 1989, 19, 278 - 285

WHAT DO YOU NEED TO KNOW TO TEACH SCIENCE IN THE PRIMARY SCHOOL?

David Symington and Dorothy Hayes

INTRODUCTION

There is recognition of the potential of science in the primary school. For example Gardner (1989) has proposed that the Government should 'develop a policy for introducing science at primary school level, for it is there that the foundation of children's interests in science are established'.

However, generally science is taught in primary schools by non-specialist teachers and various reports have recognised that these people often have a very limited background in the subject. For example, Tobin and Garrett (1988), in discussing the data they gathered on exemplary practice in science teaching, stated that "the lack of necessary content knowledge has important implications for assisting .... primary teachers to improve their teaching." (p.205). If science is to continue to be taught by generalist primary teachers a key question to be asked is: What is the most appropriate background that can be provided in the limited time available in a 3 year pre-service program? The report of a Victorian committee into science, mathematics, and technology education (Baklien et al., 1987) included amongst its recommendations the proposal that 'students training to be primary teachers study during their course at least 100 hours of a challenging level of physical and biological sciences and 140 hours of mathematics. These subjects need to include

.general studies in science and technology career awareness, and
.history and philosophy of science. (p.5)

Whilst acknowledging the significance of the issue of teacher expertise it would be reasonable to ask questions about the basis and appropriateness of this recommendation.

This paper is designed to focus attention on the issue by reporting an investigation of lesson planning by pre-service primary teachers for science lessons in a "text-book free" environment. The data were gathered as part of an evaluation of an innovative program in a pre-service methods course for primary teachers.

The Context of the Study

The staff of the Science Department in the School of Primary Teacher Education, Victoria College, involved the third year students, as part of the pre-service program, in preparing and implementing science lessons in several nearby schools. The students were formed into teams by the staff. Each team was assigned to a grade, and they prepared and implemented lessons in alternate weeks.

The student teachers were obliged to conduct lessons on particular topics. In the topic-matrix being used, for every topic there were activities defined in very general terms for each grade level. The lecturers, however, allowed a great deal of latitude, and this was necessary since the matrix was developed for normal classroom use rather than in an intervention program.

This can be illustrated by an example. The topic for one of the weeks was "flowers and fruit". Two of the groups being observed were preparing to teach Grade 1 classes. The activities suggested for the lower grades were:

Preparatory Grade:	Looking for similarities and differences in flowers.
Grade 1:	Growing plants from seeds.
Grade 2:	Grouping flowers.

Since the students were planning a single lesson, it was clearly inappropriate to consider growing plants from seeds, as was suggested for Grade 1. Accordingly, they turned their attention to other possibilities related to the overall topic. This was acceptable to the school and the lecturers.

For the planning sessions the students sat around a table on which was a collection of resources which the lecturers believed could facilitate the planning. The resources comprised teacher guides, pupil work books and a great range of natural materials, such as flowers and seed pods.

Observers sat with two of the groups during their planning and while they taught, recorded the verbal discourse and significant events. The students involved were also interviewed at the completion of the project. The analysis which follows is based on the data gathered.

The Relationship Between the Background Understanding of the Students and the Choice of Activity and Objectives for the Lesson.

The following extracts have been taken from the transcripts of sessions in which the two groups of students were each planning a lesson for a Grade 1 on "Flowers and Fruit". They have been chosen, and will be analysed, to explore the relationship between the background understandings of the students and their choice of activities and objectives for the lessons.

Group 1

Description		Commentary
Without discussion the students began to look through the printed material provided. At this point they were joined by the lecturer.		
Sally:	What about a nature trail, treasure hunt. There's one in here!	
Katrina:	Do we need to know the names of the flowers?	Katrina's concern about her grasp of the topic emerged early. The lecturer gave a response which could limit her anxiety about her personal background knowledge
Lecturer:	No. You'd have to go there and set it all up.	Despite this, as is evidenced later, Katrina continued to be concerned about her own knowledge of the topic.
Sally:	Yes	
Lecturer:	Great!	
The students continued to thumb through the books.		
Katrina:	We could get them to look at flowers and fruit with hand-lenses. How can we get flowers?	
At this stage the students were rejoined by the lecturer.		
Katrina:	What about classifying the flowers?	Katrina introduced the idea of an activity focussed on the process of classsification. She continued to press this idea for some time. This could be related to concern about knowledge
Lecturer:	Great idea! What about asking them whether trees have flowers.	

The lecturer left and the students continued to search through the books.

Sally:	I like this idea. Mark check-points. They'd have to take them to the start.	
	Draw a picture of the flowers. We'll only see flowers. We won't see fruit.	
	What are our objectives for the lesson?	As was suggested earlier, the definition of objectives appeared during the planning not at the start. Katrina continued to push for classification as the key activity.
Katrina:	Become familiar with different sorts of flowers and classify them.	
Sally:	Maybe our objective should be (that the children understand) that all plants have flowers.	
Katrina:	But I don't know enough about it myself. Do all plants have flowers?	When a concept-based objective was suggested Katrina's concern re-emerged. She again proposed focussing on the process of classification.
	Collect flowers and fruit and classify them.	
Sally:(looking in book):	There's this big tall tree has flowers. And this tiny little plant has flowers	Sally appears to be following up Katrina's question: Do all plants have flowers?
Katrina:	To recognise that plants have many different characteristics	Katrina suggested an alternative objective which broadened the focus to include more than flowers. However, Sally argued that they should restrict the focus to flowers and even to narrow the objective to the plants in the school grounds.
Sally:	Of the many different plants in our school ground	

During the planning Katrina made several references to her lack of knowledge of the topic. It is interesting to note that the activity she regularly suggested as an alternative to that proposed by Sally, the classification of flowers, was one which did not depend upon the teacher being knowledgeable about the topic.

Sally, by contrast, expressed no concerns about her background knowledge. When interviewed she claimed that background knowledge was not an issue in the lesson planning since "what one person didn't know, the other did".

Group 2

Description	Commentary
Rachel and Jan began discussing what they thought fruits were.	In this group the initial discussion focussed on their own understanding of the topic.
Jan: Something we eat	
Rachel: Something that comes after the flower, I think.	What emerged was that all three were uncertain about the definition of fruit and its relationship to flowers.
Jan: What happens after the flower?	
Fred: The bees pollinate, I think, then the fruit develops.	

All three students then looked through books. Even though the students had not resolved the issue of their background knowledge, the students began searching for appropriate activities.

Fred: What's a flower that opens and closes quickly to light? We could classify plants that way. The children wouldn't have done that before.

No one knew a plant that would react quickly to light.

They continued to look at books.

Rachel: We don't know what the children know.

Jan: I don't know anything about this topic.

Even when Jan reminds the others of her lack of understanding of the topic, the focus returns to a search for appropriate activities.

Rachel: There's an activity they might like to do.
It's flower pressing.

The students discussed a range of possible activities - classifying flowers, examining the parts of flowers. They were joined briefly by the lecturer who suggested that they could focus on the reason why plants have flowers.

Fred: We don't know enough about the topic. We need to read more.
What is the purpose of a flower?

When the lecturer suggests a purpose for the lesson it simply serves to draw their attention to their own lack of knowledge.

Jan: What's the purpose of fruit?

Rachel: We could get the children's ideas on the life cycle of a flower or fruit.

Rachel takes them back to their original focus - the flowering/fruiting cycle.

Following some further discussion they were joined by another lecturer who defined a fruit for them as "anything that has a seed"

The visit of this lecturer answers the question which appeared at the beginning of their discussion. As they begin to clarify their own ideas they realise that the children could repeat their discovery of the fact that some things commonly termed "vegetables" are in scientific terms "fruit". This was then adopted as the content for the lesson.

Rachel: So a tomato is a fruit?
I always thought it was a vegetable.

Fred: We could do a lesson sorting fruits from vegetables and have the children cut up examples.

Rachel and Jan agreed and the group went into the detailed planning of the lesson

When interviewed after the project all three of the students in this group commented on the problems they experienced in planning as a consequence of their limited grasp of the topic. They gave the following responses to the question: "In what areas of lesson planning did you have difficulty?"

Rachel: Subject matter; I'm not confident about content. Would be doing a lot more reading on the topics.

Jan: Not enough background knowledge of the topics.

Fred: Flowers and fruit - I didn't have enough background knowledge.

DISCUSSION

One of the most interesting aspects of these data is the reaction of these student teachers to the knowledge demands of the topic.

In the planning sessions observed, as was illustrated in these two case studies, various student attitudes to content issues were evident.

(i) The students drew on a very limited range of strategies to find answers to questions they themselves asked about the subject matter of the lesson.

There were many questions left unanswered. For example, in the second group, Fred asked 'What is the purpose of a flower?' and Jan asked 'What is the purpose of a fruit?' No strategies were used to find answers to these questions.

Knowledge was sought from books or by asking a lecturer. When students in the second group were interviewed after the project they lamented their lack of knowledge and proposed reading books as the means they would use to expand their knowledge.

Although Sally claimed that, when working in the group "what one person didn't know, the other did", the observers saw little evidence of the group working together constructively to achieve understanding of the content. They appeared more likely to lament their ignorance. Further, students at no time used the natural materials provided, either as a stimulus to their thinking or as a means of facilitating their own understanding. In one group when the lecturer proposed that they go into the College grounds to check out their ideas they ignored the suggestion.

(ii) The students were more likely to seek ways of developing the lesson within their own understanding than to extend their grasp of the subject to enable them to handle a possible activity.

For example, Katrina in Group 1 asked whether all plants did have flowers. Her question was never answered and the objective eventually established for that lesson was 'That most plants in the school ground have flowers'. This objective enabled the students to evade the responsibility of finding an answer to the question.

It could be argued that these students were working in an unnatural context where time was limited. However it could equally be claimed that working within such limited time constraints typifies the work of teachers.

CONCLUSION

Primary teachers will continue to be confronted with topics about which they themselves may not share the understandings of experts in the area. They are surely not alone there. Secondary and tertiary science teachers who have more extensive backgrounds find themselves in the same situation.

Increasing the number of areas in which primary teachers share the understandings of scientists would be of value. However the data of this study suggest that it would also be worthwhile to focus attention on the strategies and understandings they may use to increase their familiarity with scientist's understandings of natural phenomena. The Interactive Teaching Approach (Biddulph and Osborne, 1984) offers an appropriate model for such activity.

REFERENCES

BAKLIEN ET AL. (1987) Improving the science, mathematics and technology education base in Victoria. The report of the working group on education for science and technology to the Victorian Government through the Hon. Ian Cathie, Minister for Education, Melbourne.

BIDDULPH, F. AND OSBORNE, R. (Eds.) (1984) Making sense of our world: An interactive teaching approach. Hamilton (N.Z.), University of Waikato.

GARDNER, P. (1989) Boost for science must start with primary school children. Letter to 'The Age' 13 May.

TOBIN, K. AND GARRETT, P. (1988) Exemplary practice in science classrooms. Science Education, 72, 2, 197-208.

Research in Science Education 1989, 19, 286 - 290.

DEVELOPING ACHIEVEMENT-BASED ASSESSMENT USING GRADE RELATED CRITERIA

Ian Torrie

INTRODUCTION

In common with many other countries New Zealand has seen a shift in emphasis from the use of the traditional written examination through internal assessment towards achievement-based assessment.

In February 1989 I was asked to convene a group of five local teachers to develop a set of grade-related criteria for use in the achievement-based assessment of Form 6 (year 11) chemistry students in New Zealand. This paper outlines the process to date in the hope that it may be of use to other groups involved in similar development work, and notes that the participating teachers expressed positive attitudes about the professional development resulting from their involvement in the process.

THE N.Z. SITUATION

Since 1985 Sixth Form Certificate (SFC) has been the only national award in Form 6. SFC involves school-based assessment on a 1-9 point scale but the award is moderated by the results of the norm-referenced examinations from the previous year's assessment.

Dissatisfaction with this moderation system resulted in the Committee of Inquiry into Curriculum, Assessment and Qualifications in Forms 5 to 7 making the following recommendations in 1986.

1. That assessment in Form 6 be school-based, nationally moderated to help ensure comparability between schools, and related to course completion at four levels of achievement.

2. That in the moderation of assessment at Form 6 each subject be considered independently of others and without reference to assessment at other levels.

3. That urgency be given to the setting up of trials to investigate alternative moderation procedures for SFC subjects.

4. That urgent provision be made for the training of teachers in methods and techniques of assessment - especially of achievement-based assessment.

As a result of these recommendations the Board of Studies in conjunction with the Department of Education initiated investigations involving the use of grade-related criteria.

BACKGROUND TO GRADE-RELATED CRITERIA

Our group was asked to write the grade-related criteria (GRC) for chemistry and then to devise and trial assessment tasks that could assess achievement with respect to these criteria.

The requirements for the GRC statements were that they:

1. describe achievements in positive non-comparative language.
2. discriminate between clearly different levels of achievement.
3. provide useful information to students on what is expected and how they have fared.
4. reflect the objectives of the course.
5. assist in the assessment of all those aspects of the course that teachers need to assess.
6. satisfy the goals of descriptive reporting of students' achievement.

THE DEVELOPMENT PROCESS

The group met for three days in May 1989 to produce an initial draft set of GRC statements. The major steps involved in the development process were:

1. reconsidering the existing brief aims and objectives of the Form 6 chemistry course.
2. brainstorming the possible attributes, skills and attitudes that might need to be assessed as a consequence of the aims of the course.
3. condensing these into 14 different criteria which were then grouped under three major domains.

4. addressing the concern that the total number of criteria to be assessed required further consolidation. This resulted in 8 different criteria.
5. overcoming the difficulties encountered in writing the level descriptors. This resulted in a further revision to 6 criteria:

KNOWLEDGE & UNDERSTANDING - content
- application

INVESTIGATION SKILLS - planning
- performing
- interpreting

ATTITUDES - team work.

The group met for a further two days in November 1989 and as a result of problems encountered when applying the criteria made the following major changes:

1. The content and application elements were condensed into a single criterion called knowledge, because of the difficulty in distinguishing between recall and understanding.
2. A new criterion called communication was created because the criterion called interpreting contained more than one significant element.
3. All criteria statements were significantly reworded using more concise language.

The final draft of the descriptor statements for all 6 criteria are listed in Appendix 1.

After considerable debate at this meeting the group also made a number of general recommendations. These were:

1. that each criterion be assessed on 3 separate occasions (with the exception of knowledge and performing which could be assessed on 4 occasions).
2. that each assessment task be used to assess a maximum of 3 different criteria with 2 being optimum.
3. that a maximum of 10 assessment tasks be used throughout the year.

Finally the group produced three sample assessment tasks with marking schedules to show how some existing assessment items could be modified for use in achievement-based assessment using grade-related criteria.

At our next meeting we intend to develop more innovative assessment tasks that will encourage teachers to use a wide range of assessment modes. Hopefully these items will illustrate how the GRC can be interpreted uniformly in practice by different teachers without compromising teacher flexibility and creativity.

CONCLUSION

Participation in the development process has been demanding but has provided the teachers involved with considerable opportunities for professional stimulation and growth. The use of grade related criteria has led to a greater focus on course objectives in teaching programmes, with skills rather than content being emphasised. Positive effects on the teaching process have been noted by all and some of the teachers are considering introducing achievement-based assessment to other levels.

The need to match assessment criteria to syllabus statements has highlighted the need for the latter to offer very clear guidelines as to course objectives, levels of difficulty of content, and the relative importance of the various course components.

The writing of criteria statements is difficult and further refinement will be needed. Although the preparation of suitable assessment tasks is time-consuming the actual marking time is considerably reduced. In the course of the process described many of the teachers decided that their present assessment tasks were not assessing what they had intended, and they often rejected them as being mediocre. This highlights the difficulty for skilled teachers of monitoring and reflecting on their assessment procedures. Current expectations placed on teachers are not always realistic.

Indeed even after a year's involvement with the program the teachers still found difficulty in accepting that the descriptor for level 2 was not automatically half the value of the descriptor for level 4. Similarly when assessing criteria such as understanding it was hard not to think in norm-referenced terms, and this had not been helped by the necessity to work within the constraints of the current norm-referenced system. Clearly all teachers would need considerable exposure to resource material and in-service courses before a major shift in assessment strategies from a norm-referenced to an achievement-based system could be introduced.

APPENDIX I

CHEMISTRY : GRADE-RELATED CRITERIA 1989

KNOWLEDGE

1. Recalls some chemical ideas.
2. Recalls most chemical ideas.
3. Applies some chemical ideas to familiar situations.
4. Demonstrates an understanding of chemical ideas by applying them to familiar situations.
5. Demonstrates a full understanding of chemical ideas by applying them to unfamiliar situations.

PLANNING

1. Selects some procedures.
2. Links some procedures.
3. Constructs a plan.
4. Constructs a logical plan that could lead to a valid conclusion.
5. Constructs a comprehensive plan that could lead to a valid conclusion.

PERFORMING

1. Attempts to use procedures.
2. Uses procedures.
3. Demonstrates some skill in using procedures.
4. Demonstrates skill in using procedures.
5. Demonstrates a high level of skill in using procedures.

INTERPRETING

1. Organises information.
2. Collates information and recognises some relationships.
3. Collates information, recognises relationships and attempts to draw conclusions.
4. Collates information, recognises relationships and draws valid conclusions.
5. Collates information, recognises relationships, draws valid conclusions and attempts an evaluation.

COMMUNICATING

1. Presents some information.
2. Presents information with some accuracy.
3. Presents most information clearly and accurately.
4. Selects and uses appropriate ways to present relevant information clearly and accurately.
5. Selects and uses appropriate ways to present relevant information clearly, accurately and with impact.

TEAMWORK

1. Participates in some group activities.
2. Participates in most group activities.
3. Participates effectively in most group activities.
4. Participates effectively and contributes to decision making in most group activities.
5. Participates effectively, contributes to decision making and involves others in most group activities.

Research in Science Education 1989, 19, 291 - 299

TEACHERS' USE OF ANALOGIES IN THEIR REGULAR TEACHING ROUTINES

David F Treagust, Reinders Duit,
Ivo Lindauer and Paul Joslin

INTRODUCTION

Over the past decade, there has been considerable interest among science educators about teaching and learning science through the use of analogies. For example, the thematic research work of Clement (1978, 1987) and Glynn (1987, 1988) and their colleagues and experimental studies by Black and Solomon (1987), Gabel and Sherwood (1980) and Sutula and Krajcik (1988) provide a substantial foundation for futher investigations.

There are many definitions in the literature of an analogy; in this study an analogy refers to comparisons of structures between domains and is close to the standard analogy described by Clement (1978) and the general concept of analogy described by Gentner (1980). An analogy is a relation between parts of structures of two domains and may be viewed as a comparison statement on the grounds of structures between two domains pointing to some resemblances. A classical example is the water analogy for the electric circuit. In accordance with the use of terms in the literature (see Glynn, et al. 1987), the analog is the domain used as the basis for structural comparisons (e.g. the water circuit) and the target is the domain to be explained (e.g. the electric circuit).

A review of the research on the role of analogies, similies and metaphors in learning science has recently been conducted by Duit (1988). In concluding his extensive review, Duit (1988 p.36) writes that the advantages of analogies follow from their significance within a constructivistic perspective of learning in that:

(1) They are valuable tools in conceptual change learning, they open new perspectives.
(2) They may facilitate understanding the abstract by pointing to similarities in the real world.
(3) They may provide visualisation of the abstract.
(4) They may incite students' interest and insofar may have a motivational function.

(5) They force the teacher to take students' prior knowledge into consideration. Analogy use may further reveal misconceptions in areas already taught.

However, Duit (1988 p.37) further emphasises the point made by Glynn (1988) that an analogy is a double-edged sword in that it may totally mislead learning since

- an analogy is never based on a total one-to-one fit between analog and target,
- analogical reasoning is only possible if the intended analogies really are drawn by the students, and
- spontaneous use of analogies prepared by teachers or learning media does seldom happen.

The research into analogy use in science education identified by the authors tended to either involve training teachers to use analogies in problem solving and to subsequently observe student understanding (for example, Clement, 1987) or examine how analogies are used in textbooks (for example, Glynn, Britton, Semrud-Clikeman and Muth, 1987). No research would appear to have been reported which has examined how teachers in their regular teaching routines use analogies to help students comprehend concepts. Consequently, the purpose of this research was to address this aspect of research in analogy use by science teachers. No attempt was made in any way to influence the teaching practices of the science teachers.

METHOD

An interpretive research method (Erickson, 1986) was used to investigate the nature and frequency of analogy use by science teachers. The method incorporated data collection, data analysis and data interpretation procedures.

Sample

A senior high school science staff in the Perth metropolitan area was approached to be involved in the study. Of the eight science teachers on the staff, seven agreed to participate; a teacher in her first year of teaching wished not to be included in the study. All seven teachers had experience ranging from 8 - 20 years in the classroom and each agreed to accept a researcher in their classroom. In total, the seven teachers taught 11 different courses ranging from lower school science topics (forces in nature, ecology, energy) to upper school courses of physics, chemistry, biology and human biology. Of the seven teachers, six were Australian-born Caucasians and one was of Chinese descent.

The school is situated in a low to middle class area and has a student population with a diverse cultural background. Approximately twenty percent of students speak English as a second language at school and speak their native language in the home. The school has an effective tutor-group programme and morale in the school is relatively high.

Data Sources and Data Collection Techniques

The researchers made observations and collected data during four weeks of third term, 1988. Sources of data primarily involved the field notes about what happened in the classroom during all types of lessons taught by the teachers. Discussions about the use of analogies in science teaching were conducted with each science teacher following the four weeks of osbervations in the classroom. The members of the research team attended as many classes as was possible during this four week period.

Data Analysis and Interpretation

Analysis of data took place over the duration of the study. The research team met each week to discuss substantive and procedural aspects of the study. The overall purpose of the team meetings was to construct a complete interpretation of the data which was formulated into assertions based on a decisive balance of evidence favouring such assertions. Discrepant counter examples were identified and investigated. The validity and reliability of the assertions were carefully considered by triangulation using supportive data from as many sources (mainly the field notes from the lessons and discussions with the teachers) and among as many researchers as possible. As assertions were framed, modified and supported they were grouped with other assertions in a more general and inclusive form.

RESULTS

Based on the observations of 40 lessons of 70 minutes duration taught by seven experienced science teachers from one science staff in a large Perth metropolitan area senior high school, six assertions were formulated. These assertions are developed from all the observations and do not compare teachers of different subject areas.

Assertion 1: Few analogies were used by the teachers in their teaching routines

Based on the field notes from 40 lessons, only 8 clear indications of analogy use were reported. Most of these analogies were of a simple comparison type or were used in a limited way. Sometimes analogies were not used although they were sometimes provided by the textbook. Furthermore, in a considerable number of lessons, examples were employed which in principle provided analogical potential. While these examples could have been used as analogies, the teachers chose not to use them in this way.

Assertion 2: Teachers employed analogies in a limited way.

In six of the eight lessons where analogies were used they were addressed in a limited way. One of the teachers used analogies of the "simple comparison type". In a Year 12 biology lesson on co-dominance in genetics she compared, for instance, coat colors of cats and cows, "... it is like a cat with black ears and a cow with spots on the body". When clarifying the terms rough and gracile skeletal features she indicated that "gracile is like smooth, delicate, grace etc." In another lesson she stated that axolotls are like tadpoles of lizards, i.e. she made a comparison statement pointing to similarities among examples. A more advanced analogy was also observed in a Year 11 human biology class when the teacher explained that "DNA is like a lock and key model". However, there was no further use of this analogy.

Analogies of considerable instructional potential were used in two subsequent lessons on genetics by another teacher of Year 11 human biology. He employed a pop bead model as analog to explain features of chromosomes. But the potential of these analogies were not utilised in as complete a way as might have been possible. Furthermore, limitations and misleading aspects of the analogies were not discussed by this teacher in this lesson.

Assertion 3: Exemplary use of analogies was infrequent.

In only two out of 40 lessons was exemplary use of analogies observed, both in physics lessons. Within the discussion of the concept of half-life in radioactive decay in a Year 12 physics lesson, the teacher drew several analogies between the target concept and probability controlled games like lotto or dice throwing. In this analogy the teacher explained that every nucleus has the same probability to be changed (to another element) in much the same way as every lottery player has the same chance of selecting the correct number. Not only was this particular analogy a perfect example of our working definition of a relation between parts of structures of two domains (the radioactive nuclear decay process and the selection of number in a lotto draw), it was also taught in an exemplary manner. The teacher discussed the limitations of this analogy with the students, namely the fact that in nuclear decay, time is involved as chance in a certain time but in lottery it is not.

The teacher also briefly mentioned the aspect of luck. In further elaborating this analogy, the teacher employed the tossing coin analogy in order to explain that after two half-lives, not all nuclei have changed but there are still 25% left. He further explained some common misunderstandings of this point. This part of the lesson was defined as being exemplary because the teacher not only went to lengths to clearly show the relationship between the analog and the target but he also dealt with the limitations, explaining common misunderstandings with this analogy.

In a lesson on electricity another teacher employed two analogies. Following the traditional analogy between the electric circuit and a water circuit, fruitful as well as misleading aspects were discussed when the analogy was used to "remedy" some major students' misunderstandings. Secondly, the teacher drew analogies between three different types of fields, the electric, the magnetic and the gravitational fields. Especially analogies between the electric and the gravitational fields were given much attention. There was an interesting switch between the fields to be observed. The teacher changed the roles of analog and target several times, that is he used the electric field to work out features of the gravitational field and vice versa.

Assertion 4: Teachers had an unclear understanding of an analogy

There is a seeming contradiction between the rather rare use of analogies as outlined in the previous assertions and the fact that some teachers interviewed were of the opinion that they used analogies frequently. However, these teachers were not always sure what analogies really were. The interviews revealed that teachers were especially unsure in which way analogies and examples are different. Some teachers thought analogies and examples were the same, while others were more cautious in stating they are the same idea. Another interesting view was given by one teacher: analogies are with students' experiences whereas examples quite often are not. The outlined difficulties to adequately differentiate between examples and analogies explain the seeming contradiction mentioned above because teachers frequently used examples to emphasise and illustrate aspects of their teaching.

As another example of unclear understanding of an analogy, in a practical lesson on optics in Year 11, the teacher explained to the students that to find the focal length of a convex mirror it is necessary to use the no parallax method. He further explained prior to the laboratory that to understand the position of an object's image in the convex mirror it is necessary to use an analogy, namely to use a pencil or ruler behind the mirror to locate the position of the object in the mirror. While students understood the procedure and followed the similar explanation in the laboratory manual, this is not a use of analogy in teaching, but rather is an example of directing students to use a concrete prop to help them grasp and interpret a difficult concept.

Assertion 5: Teachers were aware of advantages and disadvantages of analogies.

Among the meanings some of the teachers attached to the term analogy were advanced and elaborated comparison statements between an analog and target domain. The teachers interviewed were aware of both advantages and disadvantages of analogies though these were differently elaborated by individual teachers. Some analogies observed in lessons were given in the interviews too, for example, the water analogy of the electric circuit and the pop bead analogy for chromosomes. Other analogies were added when discussing advantages and disadvantages: the bath sponge as analog for air compressibility and analogies between light, sound and water waves. One teacher gave an interesting type of analogy which is quite different from the ones mentioned so far. It may be called "personal analogy" (see for example the work by Clement (1978) and by Dreistast (1968)). For example, students are asked to think they were electrons in the electric circuit, or atoms in chemical bonding systems. According to the teacher these analogies may connect abstract concepts with familiar feelings.

With regard to the advantages of analogies, these were generally seen as tools to ease learning, especially in difficult topics where, for instance, prior misconceptions have to be overcome. Analogies worked because they drew comparisons between the analog and the target domain. According to comments from the teachers interviewed, analogies may help to show that knowledge is interwoven in that relations in the net of knowledge may be emphasised. Analogies may be employed to relate the abstract physics to the real world and may relate the concepts under study to what is already known. They also may open new points of views in that they "turn around the picture and give another perspective" as one teacher put it. Furthermore, analogies may visualise, i.e. may make an invisible abstract thing visible; for example the water analogy of the electric circuit visualises the invisible electric current.

Some of the teachers were not only aware of advantages of analogies but most teachers were aware of disadvantages too. They knew that analogies may mislead students' learning because the features of analog and target never fit totally. The above mentioned "personal analogies", for instance, may be misleading because the students may transfer behaviour of human beings to objects like electrons. Another aspect of misguidance was mentioned by one teacher when pointing out that analog and target are often quite different ontologically (water waves, for instance, are very different from light waves). An important aspect was also mentioned by one teacher of physics, namely that the teacher (or the scientist) may be able to see the analogy whereas the student often does not. Similarly some of the teachers were aware that there may be a big conceptual "jump" necessary to understand the analogy.

Assertion 6: Teachers did not have a repertoire of good analogies

This study has revealed some important reasons why teachers seldom used analogies although they were mostly convinced of the advantages of doing so. It appears not only to be their awareness of analogies' dangers being responsible for teachers reserve. There is some evidence from the data that teachers do not always have a clear understanding of what analogies really are. Of greater importance appears to be that the teacher sample did not have a repertoire of good analogies to use in their daily teaching routines. Indeed, most teachers did not have a working knowledge of analogies and how analogies can be used effectively in the classroom. Given the type of analogies used, which were usually presented without limitations, it is likely that the teachers have had no training in analogy use and have not developed their own knowledge base for using analogies in teaching.

CONCLUSION

Previous research has investigated the ways in which experts and novices employ analogies to solve physics problems (Clement, 1978), and the ways in which students understanding changed when they were presented with analogies (Black and Solomon, 1987; Gentner and Gentner, 1983; Glynn, 1988). The results of these and many more studies have been somewhat ambiguous.

The study reported here sought to examine how teachers used analogies in their day-to-day teaching routines. No other literature was identified which addressed a similar goal. The results of the study, completed with a sample of seven staff in a senior high school for four weeks in one term also provide ambiguous data. The teachers in this study used few analogies in their teaching and tended not to use them in an elaborate manner even when such analogies were in the textbook used by the class. The teachers in this study did not have a repertoire of good analogies to use in specific teaching situations and this may account for their lack of use. While the teachers tended to appreciate the beneficial and detrimental issues related to teaching and learning by analogies, they may have been unwilling to use analogies about which they were less confident than their normal explanations used in class.

The tentative findings of the study in one school with seven staff is recommended to be repeated elsewhere to ascertain if the six assertions can be supported. Certainly, research on analogies in teaching (see Duit, 1988) supports the view that analogies may be powerful tools in learning science from a constructivistic perspective in which conceptual change learning is a key aspect. More empirical data are needed to ascertain the type and frequency of analogies used by science teachers in their regular teaching routines prior to making decisions about how to recommend a greater inclusion of analogy teaching in preservice teaching, postgraduate programs or inservice courses.

Note: This study was conducted during the time the overseas authors were on study leave at the Science and Mathematics Education Centre, Curtin University of Technology.

REFERENCES

BLACK, D. & SOLOMON, J. (1987) Can pupils use taught analogies for electric current? School Science Review, 68, 249-254.

CLEMENT, J. (1978) The role of analogy in scientific thinking: examples from a problem solving interview. University of Massachusetts, Department of Physics and Astronomy.

CLEMENT, J. (1987) Overcoming students' misconceptions in physics: the role of anchoring intuitions and analogical validity. In J.D. Novak (Ed.). Proceedings of the Second International Seminar on Misconceptions and Educational Strategies in Science and Mathematics. Vol III, Ithaca: Cornell University (pp.84-97).

DREISTADT, R. (1968) An analysis of the use of analogies and metaphors in science. The Journal of Psychology, 70, 97-116.

DUIT, R. (1988) On the role of analogies, similies and metaphors in learning science. Institute for Science Education, University of Kiel, West Germany.

ERICKSON, F. (1986) Qualitative methods in research on teaching. In M.C. Wittrock (Ed.). Handbook of Research on Teaching (3rd Edition). New York: Macmillan.

GABEL, D. & SHERWOOD, R.D. (1980) Analysing difficulties with mole concept tasks by using familiar analog tasks. Journal of Research in Science Teaching, 17, 843-851.

GENTNER, D. (1980) The structure of analogical models in science. Cambridge, MA: Bolt, Beronek and Newman, Inc.

GENTNER, D. & GENTNER, D.R. (1983) Flowing waters or teaming crowd: mental models of electricity. In Gentner and Stevens. Mental Models. Hillsdale: Lawrence Erlbaum (pp.99-128).

GLYNN, S.M. (1988) The teaching with analogies model: explaining concepts in expository texts. Newark DE: International Reading Association.

GLYNN, S.M., BRITTON, B.K., SEMRAD-CLIKEMAN, M. & MUTH, K.D. (1987) Analogical reasoning and problem solving in science textbooks. In J.A. Glover, R.R. Ronning and C.R. Reynolds (Eds.). Handbook on creativity: assessment, research and theory. New York: Plenum Press.

SUTULA, V.D. & KRAJCIK, J.S. (1988) The effective use of analogies for solving mole problems in high school chemistry. Paper presented at the annual meeting of the National Association for Research in Science Teaching, New Orleans, LA.

Research in Science Education, 1989, 19, 300 - 310

MEANINGS AND VALUES FROM SCIENCE TEXTS

R. John Werry.

INTRODUCTION

There appears to be a persistent commitment by science educators and curriculum writers to an image of school science which is objective and value free (Millar 1985). Kooster (1988) defined a value to be "anything of importance to the individual", ie. what an individual regards as personally significant. In this broad sense, this notion of value embraces not only ethical positions, but also those subjective personal and cultural imperatives that lead to value judgments. In the educational context, these value judgments may relate (by the learner, teacher and curriculum writer) to content of courses, organization of content, and styles of teaching or learning. In this sense, school science is not value free, but adopts a certain value position.

Millar (1985) has argued that the public image of the idealized practising scientist provides a cultural resource for curriculum writers. Millar argues that the characterization of scientists and their activities may be best described by the 'Institutional Imperatives of Science' (Merton 1972):

1. Universalism: Claims of truth are outside the personal interests of the researcher (objectivity).
2. Communism: Scientific knowledge or information is shared by the whole scientific community (non-secrecy).
3. Disinterestedness: Scientists pursue truth rather than just belief (dispassionate)
4. Organized Skepticism: Scientists suspend judgment until beliefs are empirically tested (rationality and open mindedness).

These 'professional ethics' of the practising scientist constitute a specific value set (termed Mertonian norms), which commonly permeate both science curricula and texts due to the use of the image of the scientist (Blance 1985, Werry 1990) and the notion of the student as scientist (Gauld 1988).

The public image of a scientist has common use as a role model for both training future scientists and also in developing desirable attitudes and skills in future non-scientists (Millar 1985). A further use for text and curriculum writers involves the utilization of the image as a structuring device to effectively organize scientific information and concepts in curriculum material, science texts and classroom content.

This paper reports on a study of the effects of a non-Mertonian value structured science text with students of differing value orientations, and the subsequent effects on student access to text based information.

VALUE STRUCTURE OF TEXTS

The major characteristic of a 'considerate' (ie user friendly/ learner accessible) text was identified by Armbruster and Anderson (1985) as coherence, that is how smoothly ideas are woven together:

> In a coherent piece, the relationship among ideas must be clear enough so there is a logical connection or flow of meaning from one idea to the next.

Coherence effects can be identified at both the local and global level. At the local level, coherence effects assist the reader/learner integrate the information and concepts embodied within and between sentences. Local coherence features include sentence construction and how well concepts are explained in particular sentences.

At the global level:

> A text is coherent to the extent that it facilitates the integration of high level ideas across the entire discourse. (Armbruster and Anderson. 1985)

Global coherence is a function of the structure chosen to arrange content. Some principle or set of guidelines or model, organizes the local content of scientific knowledge into some coherent whole. Global effects give meaning to, and between the scientific concepts embodied in individual sentences. Meaning in this sense relates to the significance or import of the concepts or structure to the learner. This sense of the term "meaning" is used throughout this paper.

As the image of the scientist is embodied in science texts, at the heart of the structure of such texts are the Mertonian norms of Communism, Organized Skepticism, Universalism and Disinterestedness. Indeed, the values of the idealized practising scientist constitute a major aspect of the organizing structure of such a text, the Mertonian norms welding information into an integrated and coherent whole. Thus a large proportion of the global coherence (or lack of coherence), for the learner relates to the meaning generated for the learner by the organization of scientific information by the rhetoric of the practising scientist. If the values that give structure to the information fail to give meaning to the learner, then the considerateness of the text is low.

HYPOTHESIS

Considerations of the values of the learner and the global coherence of texts gives rise to the hypothesis that meaning (ie personal significance) and interest is determined by the extent of the interaction between the values of the learner and the values undergirding or organizing information in a text.

It follows that meaning is high when the text and student values coincide. Meaning is low when little or no overlap of text and student values exist; ie when the student attaches little personal significance to the values underlying the text. Further, student comprehension of information contained in a text is heightened, if the learner finds the organization of information meaningful and engaging. When meaning generated to the student by text organization is low, student access to the information is retarded and comprehension of the information is lowered.

From the hypothesis, it follows that accessibility of text information (as found in traditional organizations) depends on the extent the individual finds the values of science personally significant; ie to what extent they have accommodated these values into their personal value set.

METHOD

An alternative values based Year 11 chemistry text was developed as a test item (see box 1). The essential feature of the value structure was an emphasis on the conflicting personal viewpoints of two people/ scientists around a science based issue. The method of text construction was adapted from Egan (1985) into a cartoon story format (Werry 1990). Abstraction of much conceptual material onto a facing page, enhanced the global coherence of the storyline (Armbruster and Anderson 1985), while giving a standard 'textbook' flavor to the item.

Two different test items were developed to gauge reproducibility of results in terms of organization effects, and not in terms of the particular issue chosen, background knowledge or or conceptual difficulty of scientific information in the test item. One of the items involved environmental and economic arguments around the issue of acid rain in the topic of acids and bases, while the other involved public health and economic arguments around the issue of chemical waste storage for the topic of redox reactions.

A survey consisting of some 20 different response items was constructed to obtain student responses on: (1) Student intention of attempting Year 11 science, (2) The student's favorite subject, and (3) Assessment of alternate (cartoon) chemistry text.

103 students were surveyed : a Year 11 Math B class from an academic middle class high school, and 4 Year 10 science classes from a "conservative" working class high school. Students were simply given one of the test items and survey, and asked to read the material and complete the survey. No teacher assistance was given.

20 students participated in a taped interview a few days after they were surveyed. Students were interviewed alone for a duration of approximately 25 minutes.

Student data was analyzed by separating respondents into four categories on the basis of actual or intended course selection at Year 11, and the student's favorite subject. The categories were:

Group A (A's): Students intend to, or are doing Year 11 science and listed science as their favorite subject.

Group B (B's): Students intend to, or are doing Year 11 science, and listed a non-science favorite subject.

Group C (C's): Students are not doing Year 11 science and listed a non-science favorite.

Group D (D's): Students are not doing Year 11 science, have a non-science favorite subject and made a voluntary expression of an extreme dislike of science (eg "Science disgusts me. I hate it").

These categories of science-likingness were assumed to reflect the extent of adoption or accommodation of Mertonian norms into their personal value set. In other words to what extent the individual values the Mertonian norms.

Box 1. Structure and features of cartoon test item

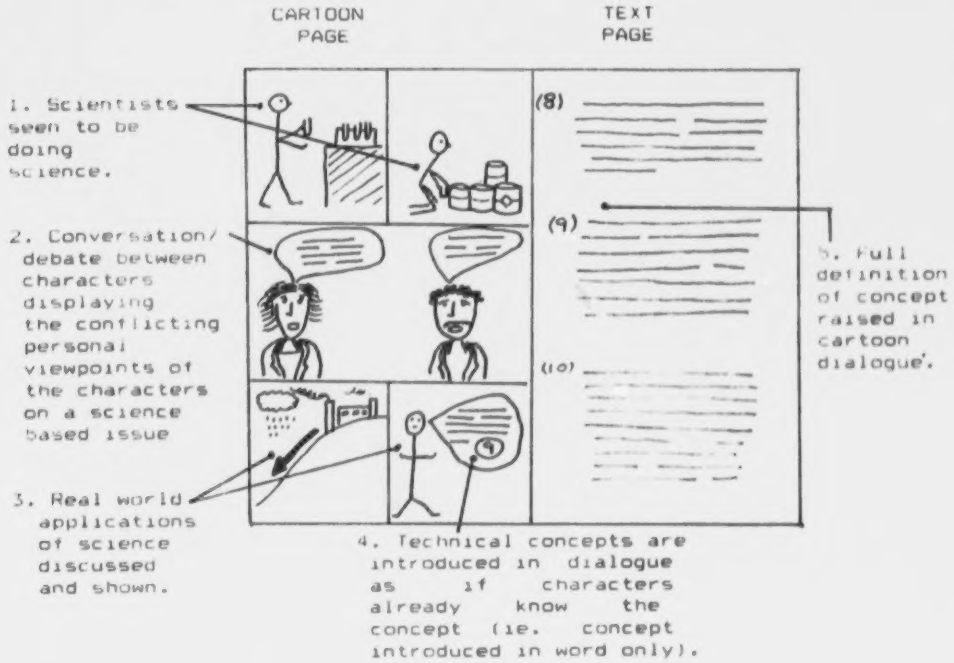

CARTOON PAGE
TEXT PAGE
1. Scientists seen to be doing science.
2. Conversation/ debate between characters displaying the conflicting personal viewpoints of the characters on a science based issue
3. Real world applications of science discussed and shown.
4. Technical concepts are introduced in dialogue as if characters already know the concept (ie. concept introduced in word only).
5. Full definition of concept raised in cartoon dialogue.
(8)
(9)
(10)

TABLE 1: SAMPLE POPULATION

		STUDENT CLASSIFICATION			
		A	B	C	D
SURVEYS:	YEAR 11	9	8	3	-
	YEAR 10	15	23	33	12
	TOTAL	24	32	36	12
INTERVIEWS:	YEAR 11	3	2	1	-
	YEAR 10	5	2	7	1*
	TOTAL	8	4	8	1*

RESULTS AND DISCUSSION

Survey Responses.

No significant differences in student response patterns were found between groups using either test item. This perhaps indicates that the value structure of the test items had a greater effect on student response, than did familiarity with topic, issue addressed or specific personal viewpoints contained in the cartoon storyline.

TABLE 2: PERCENTAGE AGREEMENT TO SURVEY QUESTION

QUESTION	YEAR 10 CATEGORY					YEAR 11 CATEGORY			
	All	A	B	C	D	All	A	B	C
1. Is the cartoon text interesting?	65	67	73	64	50	70	55	88	67
2. Would you like to see more of item?	76	67	83	88	42	70	44	88	100
3. Is the level of the text									
(a) Too high?	7	2	9	6	-	5	-	12	-
(b) Too low?	13	20	13	9	17	40	72	12	-
(c) Just right?	77	67	78	79	83	55	28	75	100

Although a majority of students from all groups responded that the cartoon test item was interesting, greater interest was generated for the two B groups. Further a greater desire was expressed by the B's and C's at both schools, to see more cartoon text material. In short, increased interest was generated for the B's and C's by the organization of scientific content into a format involving non-Mertonian values. The low affirmative response from the Year 10 D's, may be due to their expressed anti-science bias, even if scientific concepts are organized by non-Mertonian values. The significantly lower affirmative responses from the Year 11 A's (in particular to the question of desire for more cartoon style text materials) compared to the Year 10 A's, are possibly due to greater accommodation of Mertonian norms by the Year 11 students (which may be expected with a greater exposure to school science). It may also be that being familiar with the standard text format, they have little desire to learn to use an alternate format.

Although the majority of students found the intellectual and conceptual demand of the test item to be 'just right', a large proportion of A's (particularly the Year 11 group) responded that the level was too low. Written responses from the A's indicated a common perception that such an organization was unsophisticated, and in particular the idea of cartoons, dialogue (human interaction) or a storyline was 'childish' or 'babyish'. This dismissal is consistent with a value conflict between the learner's values and those in the test item.

Written responses to the question, "What particular aspects of the approach did you like? Can any be improved?", were scored under various categories as a "+" for a positive (liking) comment, or "-" for a negative (disliking) comment. Examples of comments were:

(1) "I think the 'comic' business can be left out. The pictures make us look like total fools" (Year 10 A student)

(2) "I like the way it's presented in the [cartoon] text, because it is easy to understand" (Year 10 C student)

Example (1) scores a "-" for the 'cartoon', while example (2) scores a "+" in the 'cartoon' and 'easy to understand' categories.

TABLE 3: LIKES/DISLIKES EXPRESSED TO TEXT MATERIAL (%)

CATEGORY	YEAR 10 CATEGORY				YEAR 11 CATEGORY		
	A	B	C	D	A	B	C
(a) CARTOON	+27 -27	+43 -	+58 -6	+42 -17	+33 -44	+50 -	+100 -
(b) EXTRA INTEREST	+13 -	+17 -	+42 -3	+8 -	+11 -11	+38 -	+33 -
(c) SIMPLE TO UNDERSTAND	+27 -7	+52 -9	+70 -	+8 -	+33 -11	+25 -	+67 -
(d) SHOWS APPLICATIONS	+33 -	+22 -	+30 -	- -	+22 -	+50 -	- -

Few A respondents were enthusiastic about the format of the test item. Again, responses focused on the 'childish' nature of pictures and storyline. In contrast the B's and C's from both schools not only liked the cartoon/storyline format, responses indicated that they found the material interesting and more significantly, access to and comprehension of conceptual information was greatly enhanced. The D's results again may be due to an anti-science bias.

Interview results

The D's were reluctant to participate in the interview program (only one D student did so). As such, discussion of the D category interview is not included.

Only 2 of the B A's interviewed were enthusiastic about the altered format used to present information, 4 were non-committal about their individual preference, and 2 openly disliked the non- Mertonian organization. These interviewees found the test item difficult to use and also confusing,for example:

> Q: Would you like to say what you thought about it [cartoon]?
>
> A: I think it's alright, except it shows a whole lot of miscellaneous information at once instead of concentrating on one section... You're inclined to think 'I don't know all these words'. You don't understand it straight off...
>
> Q:Was it interesting?
>
> A:Not really cos I know all about it...
>
> Q:Do you think that anyone can learn from that text?
>
> A:Yeah, but I think it's a bit hard, cos it's got a whole lot of miscellaneous information. Little bits. No general headings.

The A's who disliked the cartoon text perceived much miscellaneous (incoherently organized) information, the familiar structure of the Mertonian text was missing. The test item failed to engage or interest these interviewees. The A's tended to find facts important and interesting, not the human interactions in the test item. These responses are consistent with the pattern seeking behavior of the Mertonian scientist (Millar 1985), with an object rather than a people orientation (Entwistle and Duckworth 1977).

In contrast, the B interviewees indicated that they found their current science text uninteresting and confusing. However the test item was engaging and easy to understand, for example:

> Q: So it [the cartoon] actually looks interesting?
>
> A:Yeah. And again it doesn't seem so vague and distant. Cos in a chemistry book, it's just like chemistry. Chemical equations. It's not interesting. You don't want to read it. But this is more interesting.
>
> Q:What if they talked about this sort of thing in a chemistry book... without cartoons. just talking about the effects of acids. Would that be as interesting?
>
> A:Probably not... I don't think it would because it wouldn't have pictures. It would again be distant and vague. This shows people actually going out and doing things, and putting science into everyday life and activities.

All the B's indicated that the main source of interest was seeing the activities of the scientists and the applications of science in the real world. Meaning was generated when the B's could see what science was used for.

The C's also found the test item easy to understand and interesting, while standard texts were difficult and limited comprehension. For example:

> Q: Is the comic interesting?
>
> A:Yeah. I think it is.
>
> Q:Is it fun to read?
>
> A:Yep. It's better than something like this [Year 10 text]. Like if you don't understand something, it's got it all in here [right hand page of test item]. And it's better because [it's] in more of a conversation sort of a way, instead of. I don't know, it's hard to understand this way [standard text] but this way, with it in the conversation it's got, it's easier to understand.

All the C's identified the conversations between people to be the main source of interest. Indeed most felt motivated not only to read the scientific information, but also to understand it in order to follow the storyline and see who should win the argument. Meaning was generated for the C's by interpersonal interaction, discussion and cultural value conflict.

In order to gauge the effect of an issues based, Mertonian organized text on meaning, the Year 10 interviewees were presented with a STS based

Year 11 Chemistry text (Brookes, Learmonth and Thackeray 1984) on the same issue as their survey cartoon. Students were asked for their preference of text.

All of the B's and C's displayed resistance to the standard organization, claiming it to be boring, incomprehensible, and a barrier to motivation and learning. In contrast, 4 of the 5 A's found the standard text interesting and meaningful. While these 4 A's claimed no preference of text format, two of them indicated that the standard text had the 'real' science and the depth required to satisfy them. Indeed the cartoon format was treated as a lightweight option useful for 'weak' or slow learners. Again, this indicates a loss of meaning for the A's when factual information is organized with non-Mertonian values.

SUMMARY

Particular groups found different organizations of content significant and interesting. Further the style of organization preferred appeared to be related to the science likingness of the group. This finding may be explained by the hypothesis that maximum meaning (and thus student interest and learning potential), is gained from a text, when the text organization involves the same values as those of the learner. The postulated variation of science likingness with value orientation, and the preferred style of text organization (values) for each group are summarized in figure 1.

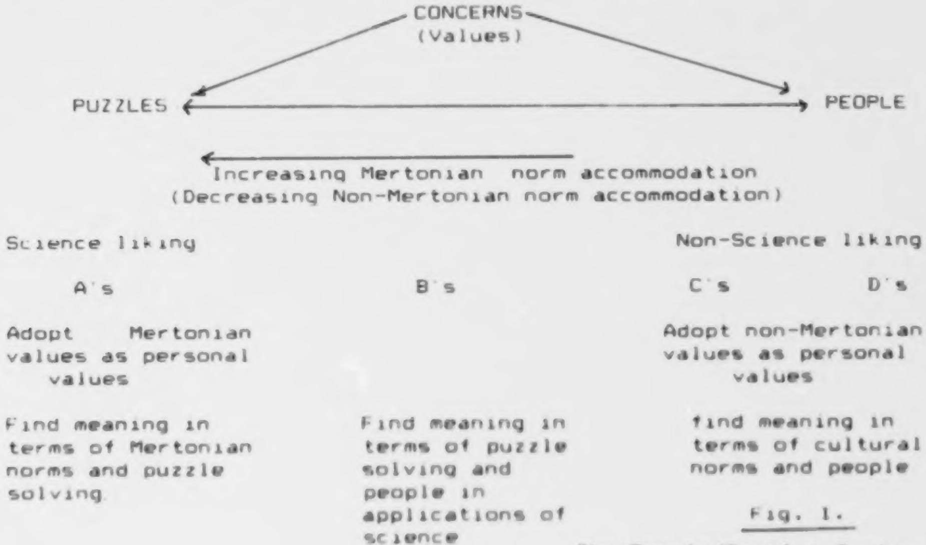

CONCERNS
(Values)
PUZZLES
PEOPLE
Increasing Mertonian norm accommodation
(Decreasing Non-Mertonian norm accommodation)
Science liking
Non-Science liking
A's
B's
C's
D's
Adopt Mertonian values as personal values
Adopt non-Mertonian values as personal values
Find meaning in terms of Mertonian norms and puzzle solving
Find meaning in terms of puzzle solving and people in applications of science
find meaning in terms of cultural norms and people

Fig. 1.

The People/Puzzles Continuum.

REFERENCES

ARMBRUSTER, B. B. and ANDERSON, T. H. (1985). Producing 'considerate' expository text: or easy reading is damned hard writing. Journal of Curriculum Studies, 17, 247-274.

BLANCE, A. (1984). School Chemistry in Victoria: Syllabus Prescription for Change. Unpublished M. Ed. thesis. University of Melbourne.

BROOKES, R., LEARMONTH, M. and THACKERAY, J. (1984). Chemistry for Year 11. Melbourne, Longman Cheshire.

EGAN, K. (1985). Teaching as story telling: A non-mechanistic approach to planning teaching. Journal of Curriculum Studies,17, 397-406.

ENTWISTLE, N. J. and DUCKWORTH, D. (1977). Choice of science courses in secondary school. Trends and explanations. Studies in Science Education, 4, 63-82.

GAULD, C. (1988). The "Pupil-As-Scientist" metaphor in science education. Research in Science Education, 18,

KOOSTER, R. J. (1988). Value issues in consumer chemistry. Journal of Chemical Education, 65, 204-206.

McCONNELL, M. C. (1982). Teaching about science, technology and society at the secondary school level in the United States. An educational dilemma for the 1980's. Studies in Science Education, 9, 1-32.

MERTON, R. (1972). The Institutional Imperatives of Science. in BARNES, B. Sociology of Science, London, Penguin.

MILLAR, R. (1985). Training the mind: Continuity and change in the rhetoric of school science. Journal of Curriculum Studies, 17, 369- 382

WERRY, R. J. (1989). A Cartoon Chemistry Text: The Construction and Testing of a Novel Chemistry Text Incorporating Human Values. Unpublished M. Ed. thesis. University of Melbourne.